BULLETIN No. 6.

MARINE FISH-FARMING FOR INDIA.

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GENERAL VIEW OF SAN CARLO FISHING STATION AND LABYRINTH, VALLE PONTI, COMACCHIO.

MADRAS FISHERIES BUREAU.

MARINE FISH-FARMING

FOR INDIA.

BY

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EXPLANATION OF PLATES.

PLATE I (FRONTISPIECE).

General view of San Carlo Fishing Station and labyrinth, Valle Ponti, Comacchio. In the centre is seen the terminal otele ; on its massive reed palisade-wall a fisherman is standing with the dip-net in his hand used for lifting out the trapped eels. To the right is a stack of bundles of reeds employed in the construction of the labyrinth walls. The building behind is used as barracks by the fishermen stationed here.

PLATE II.

FIGURE 1. Operation of freshening the water (*faire boire*) of a fish-farm at Le Teiche, Arcachon. View of the inner end of a wooden sluice.

One sluice shutter is raised to its full extent and the tide in high flood is pouring through into the ponds. Immediately under the raised wire-net screen is seen the distended bag of the sleeve net.

FIGURE 2. Seaward end of the same sluice taken at the same time as figure 1. These two figures show well the simple construction of the majority of sluices in use.

PLATE III.

FIGURE 3. View of the seaward end of the same sluice as in figures 1 and 2, during the operation of *déboire*—the letting out of a portion of the pond water preparatory to "freshening." In this operation the photograph shows that the sluice shutter is raised very slightly in order to obviate the production of a strong current from the ponds to the sea.

FIGURE 4. The same sluice closed. Note the great length of the sleeve-net suspended between its frame and the sluice-gate for the purpose of drying.

PLATE IV.

FIGURE 5. Le Teiche fish-farm. Seaward end of a closed sluice having concrete walls. The outer wire-net screen is lowered to rest in its grooves. The flat nature of the adjacent country is clearly indicated.

FIGURE 6. View of the inner end of a double sluice-way at Jacquets, Arcachon. The sluice-gates are closed and the sleeve-nets raised for drying. Note the solid construction of the sluice walls and the substitution of iron shutters and screws for the wooden ones seen in the preceding illustrations.

PLATE V.

FIGURE 7. Fish labyrinth, Serilla Fishing Station, Valle Vacca, Comacchio. View from the covola looking towards the apex of the first set of palisades.

FIGURE 8. The same labyrinth to show a lateral otèle wherein the eels are finally trapped. The group of men at the left of the view are standing about the *baldresca*, the thin-walled chamber where the mullet are separated from the eels. A moveable hooped fish-trap is seen suspended from a pole over the otèle.

PLATE VI.

FIGURE 9. View of the terminal trap-chambers (otèli) of two twin labyrinths at Serilla Fishing Station. The substantial nature of the piles and crossbeams supporting the reed palisades is well seen.

FIGURE 10. View from within the cogolara of one of the above labyrinths looking towards the mouth of the terminal otèle or trap. Note the great thickness of the reed palisading and its inner and outer series of supporting piles.

PLATE VII.

FIGURE 11. View from Serilla Fishing Station looking towards its sea-canal (Canal Ungola). Note the nets stretched across the mouth of the canal to prevent escape to the sea of any fish which succeed in forcing the passage of the labyrinths.

FIGURE 12. A lock in a service passage leading from a sea-canal into Valle Cona. See text-figure No. 8 for the outline of a lock-shutter.

MARINE FISH-FARMING:

A DESCRIPTION OF

FRENCH AND ITALIAN METHODS WORTHY OF TRIAL IN INDIAN BACKWATERS AND DELTAS.

INTRODUCTORY.

The utilisation of ponds and lagoons for the rearing of fish from fry is an industry of great antiquity. The Egyptians appear to have elaborated suitable methods 2,500 years ago and we know that the Chinese have been successfully engaged in similar pursuits for an unknown number of centuries.

In Europe fish-farming was first practised by the Romans. We know that the fattening of sea-fish was a fashionable pursuit of the luxurious during the first century B.C. Pliny and Terentius Varro have given descriptions of these fish-ponds, amongst the most famed being those formed by Lucullus near Naples which communicated with the sea by a canal reputed to have cost more than the amount lavished by the noble owner upon the construction of his villa. This canal was fitted with sluice gates and by methods very similar to those to be described in detail on a later page, both the fry and the adults of several species of sea fish were induced to ascend the canal to the ponds. As showing the great scale on which these ponds were conceived and the success of these early operations, we have Pliny's statement that after the death of Lucullus, the fish in his ponds realized four million sesterces or not less than £40,000.

The Roman marine fish-farms in spite of their great cost are reputed to have yielded handsome profits when experience in their management was gained. None appear to have survived the Augustine age though it may well be that the establishment of fish-culture in

Comacchio lagoon owed its inception to men conversant with Roman methods of fish-farming.

Down to within a hundred years of our own time, the Comacchio and other Italian establishments on the Adriatic had no imitators and to-day marine fish-farming worthy of the name is limited to Italy and France. In view of the great attention devoted to the culture of fresh-water fishes during the past 60 years and the wonderfully good commercial results obtained therefrom especially in the United States of America and in Germany, this neglect of the pond culture of sea fish may appear strange. Two principal reasons may be given—the higher capital expenditure usually necessary to construct and organize marine fish-farms owing to the larger scale on which they have to be conceived and the general ignorance of the lines on which such ponds must be constructed and regulated. We have innumerable works in English upon fish-culture, but the authors with singular unanimity limit their descriptions and instructions to fresh water work; indeed the majority of pisciculturists appear to be unaware of the fact that sea-fish culture in ponds is practised with profit in France and Italy.

The most suitable coastal districts for marine fish-culture are those where there is a wide margin of shore lands scarcely if at all raised beyond the level of high-tide. Such lands have been formed in the main as deltaic deposits at and around the mouths of rivers. Others again arise from the drifting of sand and other debris of the land along a coast by the force of locally prevailing winds and currents and their accumulation as flats and dunes in angles of the coast line. Prevailing winds and currents may also form long sand spits parallel with the coast at the mouths of rivers and, by deflecting the river estuary in the same direction, create estuarine sheets of water often of very great area; these are known as backwaters in India, and as lagoons in Italy.

Deltaic marshes and shallow backwaters provide the best conditions for sea-fish culture on commercial lines and both are numerous on Indian coasts. The Madras coast line is specially favoured; along the western coast stretches a long chain of backwaters frequently connected and giving off innumerable branches and side creeks; the eastern coast also possesses a number of important

backwaters, as Covelong, Cuddalore, Ennore, Pulicat, and in addition possesses a great number of extensive river deltas—enormous areas of low marshy land intersected by a network of channels.

With a view to study the details of fish-culture suitable for Indian conditions, the adoption of which may make it possible to utilize eventually some considerable area of the Madras backwaters and estuarine marshes, I took the opportunity last year (1909) when on leave in Europe, to visit the two localities, Arcachon in France, and Comacchio in Italy, where the rearing of sea fish in ponds and lagoons is carried on very extensively according to practical methods which have stood the economic test of commercial conditions during several centuries in the case of Comacchio and over 60 years in that of Arcachon.

I.—FRENCH FISH-FARMING AT ARCACHON.

The physical features of the basin of Arcachon where are situated the most famous of French marine fish-farms were described briefly in Bulletin No. 5, pp. 4 to 7. As there stated the basin is a great backwater roughly triangular in outline. Its area at full tide is about 35,000 acres, or approximately one-third the size of Pulicat Lake near Madras. Like the latter Arcachon basin is margined along many sections of its shore by low-lying marshes. These are specially extensive towards the inner or eastern end of the basin where the river Leyre debouches through a network of channels. These deltaic flats and marshes when not protected by embankments are liable to be overflowed during spring tides, and at a very early date a large acreage was converted into salt pans by the erection of dams fitted with sluice gates. With the sea water admitted from the basin from time to time to supply the pans came abundant fry of eels, mullet, and bass ; these found refuge in the connecting ditches and in occasional deep pools where the salt workers saw them thrive and fatten and found them a substantial addition to their meagre fare. From this to intentional reservation of definite areas for fish-rearing is a short step, especially as it must early have been noted that such fish-rearing is a less hazardous industry than salt gathering where the harvest is at the mercy of a fickle climate. Till the middle of the 19th century the methods followed remained extremely primitive ; at that epoch consequent upon improvement in the means of transport and distribution due to the introduction of railways, this industry received much attention, methods were refined, and further areas devoted to the purpose. The trade was a very profitable one for the proprietors till about the end of last century, the expenses of upkeep being very small, and the prisoned fish bringing excellent prices in Bordeaux whenever stormy weather interfered with sea fishing. To-day the owners have to face lessened profits owing to the erection of large refrigerating stores at Arcachon and Bordeaux where reserve fish is kept in stock to meet the emergency of bad fishing weather at sea. In spite of this the fish farms are con-

sidered to give better returns than would be the case if they were drained and put to agricultural or grazing purposes.

These fish farms, or *réservoirs à poissons* as they are named at Arcachon, consist of large shallow ponds and broad waterways occupying the site of former salt pans and marshes. There is no regularity or settled usage as to shape or area ; the configuration of the old marshes and the size of the proprietor's farm are the determining factors. The principal ponds in each farm are however as broad as possible and a usual size is from 300 to 600 yards long by 80 to 120 yards in width, but as I have said there is no rule and some extend to twice and even three times a greater area. Several ponds are found on each farm connected by canals and separated by stretches of low land which furnish scanty pasturage for cattle. Each fish farm is separated from the basin by a protective dyke or bund of height and strength sufficient to prevent flooding during high tides and storms. One or more sluices in this embankment provide the means of establishing connection at will between the ponds within and the sea water of the basin without. These sluices and their proper management are the pivots upon which the system depends for its success. Through the careful manipulation of the sluice gates at the right season, outflowing currents are set up which attract the shoals of fry required annually to repopulate the ponds. Another important duty devolving upon the sluices is to keep the water of the ponds in a wholesome and well aerated condition during the period the imprisoned fry are growing to the adult stage. This process of freshening consists of two operations called respectively *faire boire* and *faire déboire*. The former allows the entry of the well oxygenated sea-water of the basin, charged too with quantities of minute life welcome to the smaller creatures within the ponds—the younger fry as well as the minute animals on which the fry feed. By the converse operation, *faire dèboire*, is expelled a proportionate amount of pond water more or less contaminated with decomposition products arising from the dejecta of the fish and from decaying vegetation ; this water is also less well charged with oxygen than the compensation water admitted from the sea.

My acquaintance with the working details of Arcachon fish-farms is due in the main to the courtesy of Monsieur Garnung of Le Teiche, who kindly arranged that I should have every facility to visit and inspect his extensive fish-farm situated in the middle of the delta of the Leyre. With true French versatility M. Garnung besides owning this fish-culture establishment, owns and superintends a large resin refinery, a well-equipped steam saw-mill, and the electric light plant which furnishes current for the street illumination of the neighbouring town of Le Teiche ; private interests however do not absorb all his attention for he still finds time to look after the welfare of the town in the capacity of Mayor.

Twice I visited M. Garnung's fish-farm and on both occasions I had the advantage of his personal guidance and explanations. The farm lies just below the level of high-tides, between creeks which lead down to the eastern boundary of the Arcachon basin. The seaward side of the farm is protected against the tide by a strong embankment formed of the clayey alluvium composing the surface of the delta. Its height, governed by the local vertical range of the tide, is usually about 12 feet ; the breadth at the base averages about 36 feet, decreasing at the summit to 6 feet. The slopes are well consolidated and are further strengthened by the growth of grass and sedges. On the majority of fish-farms the area protected by the sea-dyke is divided almost equally between land and water. The largest farm at Arcachon (Audenge) comprises an area of 168 hectares (415 acres) under water and 172 hectares (425 acres) of grazing land. M. Garnung's farm is much smaller but the same ratio persists. The water area is greatly split up, forming a series of irregular ponds connected by wide channels. Sluice gates divide the various ponds and these differ considerably in depth and in arrangement. The shallowest ponds adjoin the sluices opening to the sea, the deeper ones lie landward of the former. The seaward or entrance ponds as we may term them, are wide shallow expanses of water ranging according to the size of the farm from quite small areas up to as much as 300 to 600 yards long by 80 to 130 yards wide. The depth usually does not exceed 18 inches and frequently is no more than a foot. Towards the margins the depth is greater,

ditch-like channels having been dug to furnish depths carrying from 3 feet to 4½ feet of water where the young fish may retreat for safety upon any sudden atmospheric change. In the shallows of the entrance ponds flourishes a luxuriant growth of marine and brackish water vegetation, chiefly confervæ and a species of marine flowering plant (*Ruppia maritima*) which finds here extremely congenial conditions. The marine prairie thus formed over the shallow central portion of each pond is the home of swarms of minute life—infusorians, zoophytes, and small crustaceans and molluscs, constituting the main food supply of the young fishes. The great majority of these fish-farms and all the large ones have separate wintering ponds where the fish are herded during cold weather. These are deep canal-like ponds of sinuous course, sometimes over a mile in length by 20 to 30 feet in width. As a long length is required the course doubles upon itself so often that it becomes a veritable maze. These wintering channels are situated in the most sheltered section of each property and care is taken when excavating them to pile the material dug out as a protective embankment along the north-east and south-east boundaries as a protection against the cold winds which blow from these directions; as a further protection these banks are often planted with thick hedges of tamarisk, a plant that thrives well on the coasts of Western Europe.

Construction of Sluices.

The general plan and arrangement of the sluices which place the ponds in communication with Arcachon basin vary very slightly in the different farms; the dimensions which follow are those of a sluice on M. Garnung's property and they and the accompanying plans (text-figs. 1 to 3) and photographs (figures 1 to 5) of sluices on the same farm may be considered as typical of the form in accepted use. The differences which exist are chiefly in the materials employed and in the mechanical details of the means employed to raise and lower the sluice shutters.

The sluice now to be described is one leading into the principal entrance pond. It consists of a cutting

through the sea-dyke 32 feet long and 47 inches wide. In the more modern farms the sides and floor are of concrete, but in the older forms (figs. 1 to 4) the framework is built up entirely of fir planking supported by piles. Twenty-one feet from the seaward extremity two narrow sluice shutters are fitted sliding up and down in a grooved framework and actuated either by a screw adjustment or by the leverage of a crowbar. From this point the floor of the sluice slopes gently downwards towards each extremity so that its level at the seaward end is depressed 4 inches and that at the inner end 2 inches below the level at the sluice gates. The floor of the sluice is arranged so as to be from 3 to 4 feet below the mean level of the entrance ponds and about 2 feet above the bottom of the wintering ponds. Each extremity of the sluice (*S.* and *S.S.* text fig. 1) is furnished with a

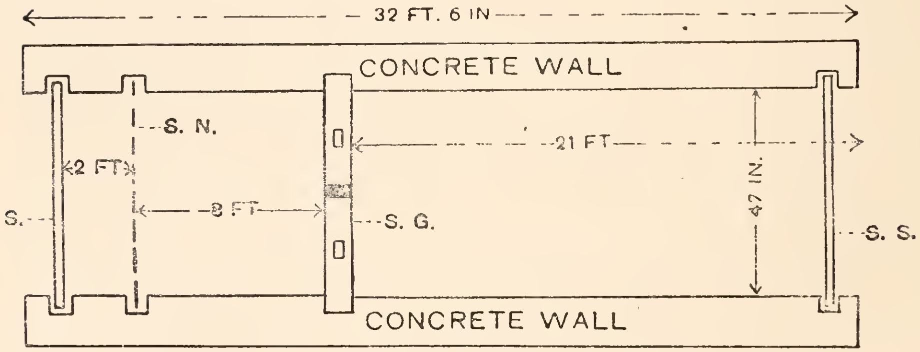
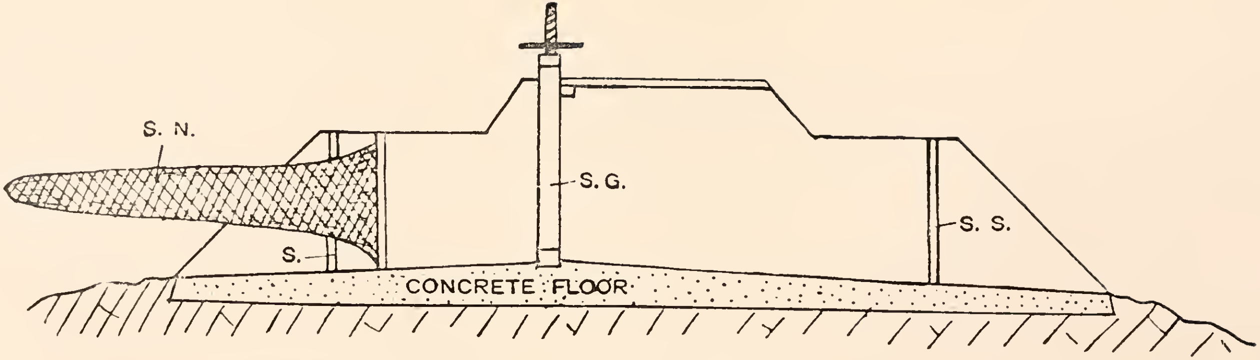
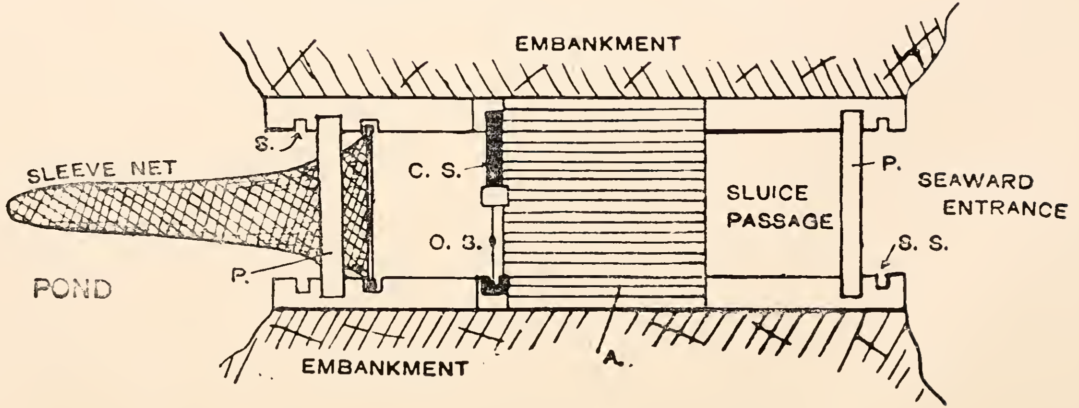


FIG. 1.—PLAN OF SLUICE TO SHOW GENERAL DESIGN AND DIMENSIONS.
S.G. Sluice gate provided with two shutters ;
S.S. Seaward wire net screen ; S. Inner screen.
S.N. Indicates position of frame of sleeve-net.

moveable wooden frame sliding in vertical grooves cut in the side walls. Over each frame is nailed a screen of strong wire netting of small mesh so that when in place in its grooves it furnishes an effectual barrier to the passage of all but very small objects. The overall dimensions of these frames are 6 feet 9 inches by 4 feet 1 inch. Eight feet behind the sluice gates and 2 feet in front of the screen at the inner end of the sluice is another pair of grooves accommodating a third frame. This instead of being covered with wire netting as are the other two has the mouth of a long tapering cotton net, the manche,



TEXT-FIG. 2.—LONGITUDINAL SECTIONAL VIEW OF A SLUICE.



TEXT-FIG. 3.—PLAN OF A SLUICE TO SHOW ARRANGEMENT DURING "FRESHENING."

A. Boarded pathway crossing summit of sluice.
P. Plank over sluice passage.
C.S. Closed sluice-shutter.
S. Groove for inner screen.
O.S. Open sluice-shutter.
S.S. Groove for seaward screen.

nailed or laced to its rectangular frame. This narrow sleeve-shaped net has a length of 23 to 24 feet; at the mouth end the meshes measure 15–17 millimetres (about $\frac{5}{8}$ inch) and diminish to 10–11 millimetres ($\frac{3}{8}$ inch) towards the free extremity. Except when letting out water from the ponds the frame of the sleeve net is kept raised to the top of its grooves, the net itself being carried backwards and hung over the framework of the sluice gates as shown in Pl. III, Fig. 4. To facilitate the working of the sluice a plank is laid across behind each of the three movable frames (see text Fig. 3.), and a plank way, 6 feet wide, crosses the sluice at the summit of the embankment.

The Method of Stocking with Fry.

This operation depends upon the fact that the fry of certain species of sea-fish resort to estuaries during the early period of their life, led by an instinct which impels them to swim against any current they encounter. Hence to avoid the labour and expense of collecting the required amount of fry in the sea by means of nets, the sluices of the ponds are manipulated in such a manner as induces shoals of fry to enter the ponds voluntarily. The operation is conducted in the following manner. Each day during the period of neap tides at the times when fry are expected, as soon as the tide begins to recede the wire screen at the seaward end of the sluice is raised, the one at the opposite end being kept in position; one of the sluice shutters is then raised sufficiently to create a current flowing from the pond to the sea. Following their instinct, any small fish which are near the sluice swim against this current and eventually find their way into the sluice channel. When the man in charge of the operation judges the time fit, either because a large number of fish have congregated or because the tide has turned and would shortly cause a change in the direction of the sluice current, he replaces the seaward screen and closes the sluice. The imprisoned fry are then fished out of the sluice with the aid of a square-framed dip-net and transferred to the adjacent pond where they are kept till such as survive to maturity attain marketable size and condition.

Spring is the season when the bulk of the fry is obtained. At this period grey mullet (*Mugil labeo*), bass (*Labrax lupus*), and eels appear in great shoals; multitudes pass into the sluices and are captured. The passage of the shoals of fry from the sea into estuaries and even up rivers is technically termed *montée* by French Culturists, a term which may be rendered into English as the ascent of the fry. Although this takes place principally in the spring in Western Europe, it varies considerably with the species and scarcely any month between February and October is without its ascent. Thus at Arcachon the white mullet (*Mugil labeo*) arrives as early as February and continues into March. The common eel (*Anguilla vulgaris*) arrives almost as soon in vast multitudes of strange transparent larvæ already about 7 centimetres ($2\frac{3}{4}$ inches) in length. Bass appear chiefly during April and May, while the shoals of the black mullet (*Mugil chelo*) do not usually come till May and June. Another and greatly esteemed mullet, *Mugil cephalus*, is still later in putting in an appearance, September and October being its months of ascent. The bulk of the fry other than of eels enters with a size of from $\frac{3}{4}$ to $2\frac{1}{4}$ inches—the great shoals are constituted of fry of this size. With the advance of the season the young fishes attracted into the sluices decrease greatly in number concurrently with considerable increase in individual size.

Of the two operations involved in the freshening of the pond water, that involved in the running off of a portion, the operation of *faire déboire*, is conducted very much in the same manner as the manipulation of the sluice when shoals of fry are to be captured. As in the latter operation, when the tide begins to fall, the screen at the sea end is either removed or raised sufficiently to give a clear passage, and then one or both of the sluice doors are raised very slightly, usually from 3 to 6 centimetres ($1\frac{1}{4}$ to about $2\frac{1}{2}$ inches) and never more than 10 centimetres (4 inches). By this means a stream of water flows from the pond into the sea and continues to flow not only till low tide, but also during a portion of the flood and until the rising tide attains an equal level with the water of the pond. At this moment, unless it has been done before, the sluice doors

are raised and the seaward screen dropped home into its grooves. A skilful operator can so judge and control the strength of the outflowing current as to keep it so weak that it has no power to carry out any of the fry in the ponds—it is for this reason the sluice doors are raised so slightly. The natural instinct of the fry to swim against a current is also counted on, while to prevent larger fish passing out the screen at the pond end of the sluice is kept lowered during *déboire*. Occasionally however the fry do endeavour to pass out in some quantity; when this is observed the sluice shutters are at once closed. When the operation is finished for the day a considerable quantity of fry and prawns are frequently found congregated in the sluice; these are caught and put into the ponds in the same manner as when stocking the ponds with fry. It must be noted that this operation of emptying a portion of the pond water is carried out usually during spring tides, whereas the operations for catching fry in quantity are carried out during neaps. This and the greater height to which the sluice shutters are raised during the latter operation—involving a stronger current—are the two important differences.

The converse operation of *faire boire*, or actual "freshening", is merely the reversal of the two operations already described. It consists of a regulated inflow of sea water during spring tides equal to the amount expelled during *déboire* and lost by evaporation. In this operation both the wire-net screens are raised (Pl. II, Figs. 1 and 2) and then before opening one of the sluice shutters the mouth frame of the sleeve-net is dropped into position, the net itself being thrown into the pond. As soon as the rising tide attains a higher level than the surface of the ponds a sluice shutter is raised slowly and with the utmost care in order that the inrushing water may be adjusted with nicety to a strength sufficient to distend the sleeve-net but not violent enough to burst it. Text-figure 3 will make this operation clear.

The scene in the pond during this process of freshening is extremely interesting (Pl. II, Fig. 1). The great 24-foot long sleeve-net, distended and appearing taut to the point of rupture, streams straight into the pond, and

all round its outer surface swarm hundred of dark bass attracted by the current, all darting to and fro in the greatest excitement either hunting for food particles brought by the inrushing tide or endeavouring to find an opening in the net and so pass up the current. Mullet being shyer fish do not press forward so excitedly as the bass do and one sees comparatively few of them. A baited hook dropped among the bass at this time is seized at once and the veriest tyro may haul them out as fast as the hook can be rebaited.

As in the other sluice operations, "freshening" requires a nice judgment on the part of the gateman, a judgment acquired only after years of experience. Thus while it may be stated as usual for freshening, in its two-fold operations of causing first an outflow and then an inflow, to be carried on twice a day during spring tides from the middle of March till the beginning of November, there is no fixed rule; the frequency and the duration of each freshening are left to the discretion of the man in charge who acts according to the varying circumstances of weather, tide, and the condition of the pond water. To a large extent the gatemen seem to be guided by that peculiar instinct or intuition gained by fishermen from years of familiarity with their calling which tells them unerringly that certain conditions are present though they may be unable to explain how they arrive at the conclusion. Usually the ponds are freshened at each tide for two days before and three days after new and full moon. During the winter season, November to March, it is not found necessary to carry on these freshening operations, the entrance ponds being then wholly or partially dry, and the fishes removed to the wintering ponds.

Feeding and Care of the Fish.

Every time freshening takes place a certain amount of food matter is passed into the ponds. In part this is microscopical life which passes the screens freely, partly it is small fish and shrimps caught in the sluice and thrown into the ponds by the gateman. Beyond this no food is given to the imprisoned fish, which are expected to forage for themselves in the aquatic herbage flourishing

in the ponds. No use of artificial food is made, though to any one conversant with the pond culture of fresh-water fishes it appears certain that such a practice would very greatly increase the success of this industry: it is obvious that a very large proportion of the fry admitted to the ponds is devoured by the stronger among the bass and eels, and were a sufficiency of suitable artificial food added to the dietary of the fish, cannibalism would be reduced, fatter and larger fish grown and a greater quantity reared to maturity. It happens however that existing methods give fairly remunerative results and the fish-farmers are therefore satisfied to leave methods as they are.

During their early days in the ponds and as long as warm weather continues, the fry frequent the shallows where they keep together in shoals, usually affecting the sunny side. On the approach of winter the mullet and the bass seek out retreats in the deeper parts of the ponds, while the eels burrow into the mud. The mullet especially suffer severely from any considerable lowering of the temperature and to protect these fishes in particular the deep wintering ponds already described are constructed whenever the proprietor can afford them; in the case of very small farms where the stock of fish held does not justify the expense of such special provision, deep holes are dug here and there in the bottom of the ponds and these are found to furnish a satisfactory alternative when the protection of a limited number of fish is in question.

On the farms where wintering ponds are provided special operations of great delicacy have to be undertaken in order to herd the fishes into their cold-weather quarters. This is effected with the aid of water gates which are interposed between the various sections of the series of ponds. The procedure is similar to that employed in the attraction and capture of fry for stock, but is much more difficult to conduct owing to the smaller volume of water dealt with. First the level of water in the shallow summer ponds is reduced to the utmost by running out as much water as possible through the sea-sluices at low tide, the doors between the summer and winter ponds being closed the while. When no more water can be got rid of, the sea-sluices are shut.

The level of the deep winter pond is now at a higher level than that of the summer pond, so when the doors separating these are raised a sufficient head of water is obtained to induce an appreciable current from the deep winter pond into the shallow summer one. The most experienced hand superintends the operation and he has need of all his skill for the volume of water available used to produce the current is very limited and does not permit of a long-continued flow. The flow must not be permitted to be too great or the winter pond will empty so rapidly that an equilibrium of level between it and the summer pond will be established long before a proper proportion of the fish have all passed upwards. Neither must the current be too weak for then the fish will fail to be attracted towards it. The operation is repeated until all the fish have passed into the deep wintering ponds. By the time this transfer is completed the shallow summer ponds, now denuded of fish, contain little or no water except in the deep ditches along their margins and in this dry condition they remain the whole winter. This annual draining and exposure of the bed of the summer ponds to atmospheric influence is an operation of prime importance to the continued prosperity of these fish-farms. An instance of the fatal result attendent upon the long-continued non-observance of this axiom of pond-culture is detailed on page 46. A severe winter is an anxious season for Arcachon fish farmers in spite of all the precautions that can be taken. They fear particularly the cold dry wind from the north-east for a tempest from that direction may so reduce the temperature of the ponds that the stock of mullet and bass may be decimated and even destroyed in a single night. During ordinary frosty weather when ice forms over the ponds care is taken to break holes in it at numerous intervals to allow some facilities for aeration.

Methods of capturing the Fish.

When they have attained marketable size the fish are caught as demand requires by one of two methods according to the species that may be ordered. Mullet, bass and eels are the only kinds which mature in considerable numbers in the ponds and while the two

former are taken whenever required by means of nets, this method of fishing is not suitable for the capture of eels. To obtain the latter in quantity recourse is had to the attractions of the sluice current at the season when the reproductive instinct of these fish renders them eager to gain the open sea and there seek the abyssmal spawning depths where they were themselves hatched. This desire develops in greater degree as autumn progresses and during September, October and November the adult eels in the ponds are ready to respond to this call of the sea. Accordingly on the occasion of any convenient spring tide during the months named the sluice gates are manipulated during one or more *night* tides, so that a strong current of sea-water is directed from Arcachon basin into the ponds. This is obtained by raising one or both of the sluice shutters at the moment when the tide has reached its highest level. Concurrently the wire screen at the pond end of the sluice is lifted, that at the seaward end remaining down. The adult eels attracted by the current thus produced come from all parts of the pond towards the sluice in the endeavour to gain the sea. Baulked of escape by the seaward screen they accumulate in the sluice till the operator judges the number to be sufficient, when both the sluice gates and the pond screen are shut down. The eels may then be removed at leisure by means of a dip net and transferred to storage boxes or live cases moored in a deep part of a pond, where they will remain till sent to market. It must be noted that large catches are made only when the nights are dark and stormy ; it is useless to attempt to attract the fish into the sluices by this method on calm or clear nights or during daylight, whence the necessity to keep large stocks of eels on hand in the store boxes.

Mullet and bass are more easily taken when required ; a trammel net set in the evening may generally be depended to yield a considerable number of large individuals when it is taken up in the morning. Hence these fish are taken only when orders arrive and when the quantity netted is greater than is necessary, the surplus are liberated as the trammel net has the great advantage among nets of inflicting little or no injury upon the fish taken in it.

Age and Rate of Growth.

Mullet and bass take generally three years to attain marketable size, while Gemzoe * has proved that eels do not seek to pass to the sea till after 4½ to 7½ years sojourn in the case of males and an even longer period in the case of females, the great range in the length of the sedentary stage being determined by local conditions and circumstances.

Mullet, which enter the Arcachon ponds as tiny fry 1½ to 2 inches long, are stated to weigh on an average at the end of three years about half a kilogram or about 18 ounces under normal conditions. But this rate of growth is considerably surpassed in the better situated ponds and when a series of warm and sunny seasons occur consecutively. Under such circumstances Millet † has claimed that 1,000 mullet fry reared in the Arcachon pond will yield 1,000 kilos of fish within three years.

The growth of the eel is considerably greater; Coste has estimated that these fish when reared in ponds attain a weight of 2½ kilograms (5½ lbs.) within 4 to 5 years, but this again varies greatly with locality and the relative amount of food supply available, and the rate of growth must be worked out independently for each separate district. Comparatively little exact research has been devoted to this subject of the rate of growth of sea-fishes; precise information upon it is urgently needed together with an analysis of the relative value of the factors which favour and retard growth.

Extent and Profits of the Arcachon Industry.

The total area of the ponds devoted to fish rearing on the borders of Arcachon basin has been estimated at not less than 300 hectares or about 740 acres. A few large properties account for the bulk of this, one farm alone having more than half the total area, others again do not amount to a full hectare.

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* K. J. Gemzoe, *Age and Rate of Growth of Eels.* (Report of the Danish Biological Station to the Board of Agriculture, xiv, 1906. Copenhagen, 1908.)

† La Production animal et vegetale. Paris, 1867.

The yield is very variable. In one year, these 740 acres are estimated to have yielded 68,060 kilos of fish, while in the succeeding year, the yield rose to 97,660 kilos.*

This is equivalent to a mean yield of 92 kilos per acre in one year and 132 kilos in the next. Another estimate† of the yield is that one hectare of water, well cared for, will give 150 kilos of mullet and 50 kilos of eels in a good season; this work out at 81 kilos per acre. This, however, I understand, is considered too low for really well organized and up-to-date culture, and I was assured that 120 kilos of fish per acre is the actual average present-day yield of large fish farms when conducted skilfully and with enterprise. A balance sheet quoted by Millet (*loc. cit.*) gives the receipts and expenditure for a farm comprising 100 hectares (247 acres) of pond surface as follows:—

Receipts.

		Francs.
Sale of fish, 30,000 kilos at 1 franc per kilo.—		30,000

Expenditure.

	Francs.	
Foreman	460	
3 Gatemen	1,050	
Nets, boats, freight of fish, etc. ...	2,500	
Upkeep of sluices and embankments (average)	800	
		4,810
		25,190

This is equivalent to a net profit of, say, 252 francs per hectare or 102 francs, say £4, per acre.

This return may appear comparatively small in view of the statement often made that an acre of water produces a greater amount of food than the same area of land; this assertion is however most misleading when stated baldly and without qualification for while some land is exceedingly rich and capable of yielding prolific crops, other tracts are virtually worthless, and so it is with the sea and rivers; there are areas where fish may congregate,

* Gobin, La Pisciculture en eaux salees, Paris, 1891.
† G. Roche, La Culture des mers, Paris, 1898.

brought together in multitudes for the purpose of spawning or to feed on some food matter accumulated perhaps in some indentation of the coast under the action of a current eddy, and here the yield per acre of surface may be prodigious. Elsewhere and even in the same places at another season fishes may be all but wholly absent. Inshore waters generally do appear to furnish larger and more valuable food returns to man than average quality of agricultural land, and the absolute productivity of the sea per acre is probably greater than that of the land. This latter is however not the question before us, which is the profit to be drawn by man from the cultivation of selected areas of shallow water.

To assess the value to a district of fish farming such as is practised at Arcachon it is more just if we consider what the same area would yield were it cultivated in any other manner, rather than make a comparison with the profit derivable from rich agricultural land. We must also consider the relative amount of labour necessitated in the cultivations compared. Considering the matter from this standpoint we shall see this profit of £4 per acre in a much more favourable light. The proprietor of the farm we have mentioned was able to make a profit of just £1,000 on the working of 243 acres of what was originally a salt marsh and this with the aid of a surprisingly small labour force—4 men in all. What form of land culture can show such a record for 4 men's work? Again, were this marsh land not utilised for fish culture, its value for agricultural purposes would be comparatively small for several years, because the land being below the level of high tides and saturated with salt, it would be a long time before it became sweet enough to yield good crops.

It must further be borne in mind that the culture system pursued is of the simplest description, so much so that in the preceding pages I have avoided the use of this term wherever possible, preferring the more elastic one 'farming'. True culture implies breeding and this the Arcachonnais have never attempted ; neither do they supplement the food supply of the ponds except by turning into them such fry and small crustaceans as are taken fortuitously when freshening the water. Up to the present time the attention of the owners has been

concentrated upon the perfecting of mechanical means for the capture and safe keeping of fry hatched in the open sea ; their system is perfect in respect of these operations but it fails to rear a sufficient weight of fish per acre as it makes no provision to supplement the limited food supply produced naturally within the ponds. As a consequence of this limited food supply cannibalism is prevalent and but a comparatively small number of fish survive. No intensive culture is attempted and until it is, Arcachon fish farming will remain an industry only partially developed and will be unable to yield the further profits which a vigorous policy of development on scientific principles would certainly yield.

At the same time it will be noted with satisfaction by French culturists that the produce per hectare compares favourably with the much vaunted results of German carp culture, an industry now highly organized and widely spread throughout that empire. Estimates of the annual produce of carp reared in ponds as given by German scientists, range from 65½ to 164 kilos per hectare *, and it seems certain that the average cannot be placed at more than 110 kilos, whereas at Arcachon we have seen that the ascertained yield per hectare for one year was 226·8 kilos and for the succeeding year 325·5 kilos. per hectare, or 276 kilos average for the two seasons. The superior results given by the empirical French methods over those directed by German science show how responsive fish-culture is to the crudest of treatment in the presence of favourable natural conditions, temperature being one of the principal. In Germany the rigors of winter are so severe that for months the growth of fish suffers arrestment, whereas at Arcachon the winters are notably mild and inclement weather is of short duration.

The illustrations on plates II to IV represent graphically the construction and method of operating the sluices of Arcachon fish ponds. Figs. 1 to 4 show sluices constructed of wood planking, while those on plate IV are two examples of more modern forms where concrete is the material employed for the walls and floor. The sluice depicted in fig. 6 is of the most modern type

* Brandt, Ueber d. Stettiner Haff, *Wiss. Meeresunt. Kiel Komm.*, 1896.

and leads into a fish pond constructed by M. Lesca at Jaquets on the western shore of Arcachon basin ; here, as may be easily discerned in the view, are two twin sluices side by side, each with a single substantial shutter, worked by an ordinary screw. In all the other views reproduced two narrow twin shutters are fitted within a single sluice way, a method inferior to the Jaquets plan as the doubling of the sluices minimises the danger of mishaps and permits of greater rapidity in the carrying out of the different sluice operations.

Figs. 1 and 2, plate II, show the operation of *faire boire*, the inflow of seawater into the ponds. Fig. 1 is of the inner or pond end of the sluice, fig. 2 being of the opposite or seaward extremity. The former view shows the inner screen and one of the sluice shutters lifted clear of the channel of the sluice ; the distended mouth end of the sleeve-net may also be discerned immediately under the raised screen. Angling for bass attracted by the inrushing current is going on briskly under M. Garnung's direction. Fig. 2 shows further details of the operation of *faire boire* while fig. 3 shows a view of the same end of the sluice during the converse operation of *deboire*. Note in this photograph the low state of the tide as compared with that shown in fig. 2 ; also that in this operation the sluice shutter is raised very slightly. The next views, figs. 4 and 5, show closed sluices. In fig. 4 the frame of the sleeve-net is seen raised and the net itself carried back and thrown over the upper frame work of the sluice gates. This position of the sleeve-net is shown again in the case of the Jaquets sluice, fig. 6, where it will be noticed that the gradient of the embankment is considerably easier than in the case of those seen in the other views. This is due to the fact that the soil at Jaquets is composed largely of sand and is therefore less easily consolidated than the clayey alluvium at the mouth of the Leyre.

FIG. 1.—FRESHENING OF A FISH-FARM, LE TEICHE, ARCACHON. VIEW OF INNER END OF A WOODEN SLUICE.

FIG. 2.—THE SAME SHOWING THE APPEARANCE OF THE SEAWARD END AT HIGH TIDE. SCREEN AND ONE SLUICE SHUTTER RAISED.

[*J. Hornell, Photo.*]

FIG. 3.—VIEW OF SEAWARD END OF A SEA-SLUICE DURING THE OPERATION OF DEBOIRE, LE TEICHE. LOW TIDE.

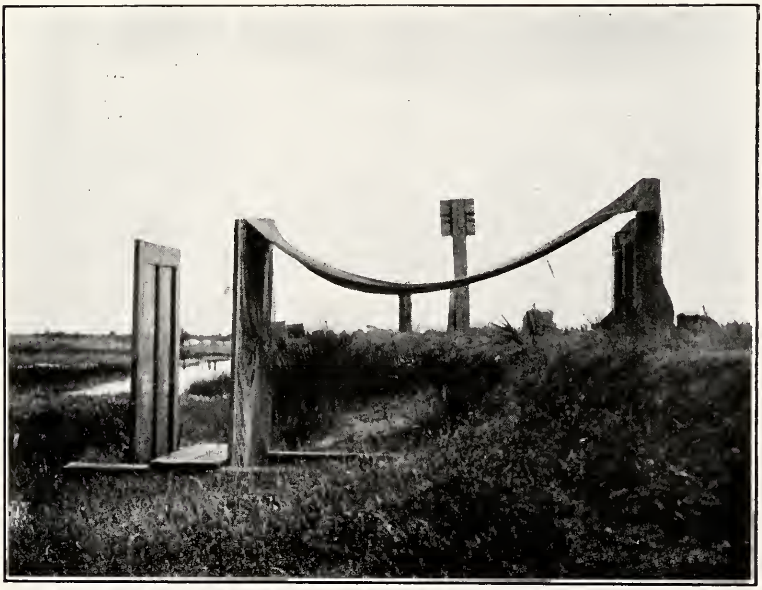

FIG. 4.—LE TEICHE FISH-FARM. INNER PORTION OF A CLOSED SLUICE SHOWING INNER SCREEN RAISED AND SLEEVE NET DRYING.

[*J. Hornell, Photo.*]

FIG. 5.—LE TEICHE FISH-FARM. SEAWARL END OF A CLOSED SLUICE WITH CONCRETE WALLS. OUTER SCREEN LOWERED.

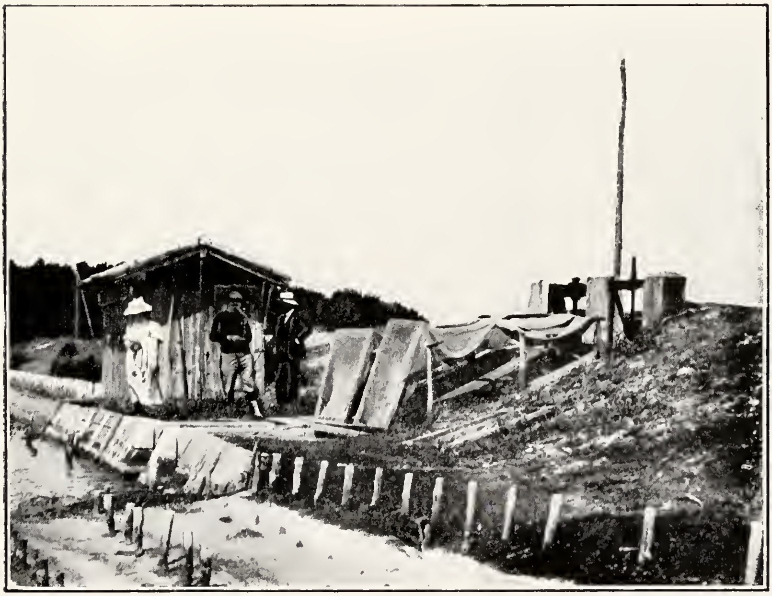

FIG. 6.—DOUBLE SLUICE-WAY AT JAQUETS, ARCACHON. SLUICE CLOSED AND NETS RAISED AND DRYING.

[*J. Hornell, Photo.*]

II.—THE COMMUNAL FISH-FARMS OF COMACCHIO.

Comacchio as the seat of the most extensive and most highly organized system of marine fish-farming in existence was brought prominently to the world's notice for the first time by the epoch-making account of a journey made by Coste, the father of French aquiculture, during the years 1853 and 1854 by instruction of Napoleon III. It is interesting to read in the official directions issued to Coste in 1852 that he was desired to explore the coast of France and of the Italian Adriatic with "a "view to determine under what conditions extensive "experiment in the propagation and acclimatization of "marine animals should be organized"; at the period in question the potentialities of the artificial cultivation of oysters and fish were occupying wide-spread attention in France and the national optimism already saw in imagination the numerous salt marshes and land-locked bays along their coasts converted into fish-ponds and oyster parks.

The results of Coste's investigations were published by the French Government in 1855 and in prefacing the dry details of the present day condition and organization of the Comacchio fish-rearing establishment, I cannot do better than translate the picturesque and graphic description furnished by Coste who thus introduced the same subject:—

"At the time when barbarians were driving the civilised peoples (of the Roman Empire) before them the population of Comacchio, like the founders of Venice, sought refuge in the bosom of an immense marsh, which, since the time when it was thus occupied, has been gradually transformed into a great establishment for the exploitation of the sea, where its methods attract fry hatched in the Adriatic and gather in a harvest of fish when these become adult, by processes as well conceived as those pursued by agriculturists in the sowing of their fields and the reaping of their crops."

"Less favoured than its neighbour Venice, and unable because of the inferiority of its position to aspire either to commercial sovereignty or to the rewards of conquest, Comacchio applied its genius to perfect an admirable system of dykes built with the mud of its lakes, made firm with fragments of the shells living in its waters, and intersected by numerous sluices opening into well-arranged canals which while

giving access to the open sea and to the fresh water of the rivers bounding two sides of the lagoon, allow control at will either of the entire lagoon or of any one of its compartments, with as much facility as one can operate a laboratory model; gigantic labour until now without renown, modestly accomplished by plain men, resigned to the rough discipline of the sea, to the monotony of barrack life, to the sacrifice of sleep during stormy nights when tempests torment the lagoon and lash its surface into commotion—satisfied as the price of so much labour with a modest wage and the ration of fish which a paternal administration distributes to them daily."

"If we imagine a fleet under the autocratic rule of an admiral charged with the oversight of all needs, to have anchored in mid-ocean, condemned there to subsist upon the produce of their fishing, communicating with the rest of the world solely for the purpose of transhipping fish into vessels coming to trade for it, we have the image of this colony whose fishing stations and barracks are scattered like ships of a squadron among the isles within this immense lake."

Since Coste's historic visit, several well-known French, Italian, and German scientists interested in fish-culture, have studied on the spot the lessons to be drawn from the practice of this great Italian fish-rearing enterprise, but I cannot learn that any British enquirer has ever inspected the lagoon. References to it in English works are both scanty and vague; for this reason and also because Coste's book, besides being difficult to procure, requires considerable amplification and amendment in the light of present day knowledge if to be of practical service to fishery authorities in India, in the following pages I propose to describe with such detail as appears material, the existing condition and organization of the Comacchio lagoon, the system by which fish fry are introduced, reared and eventually captured, the methods employed to prepare the produce of the fishery for market, together with notes upon the causes which from time to time during the past century have affected adversely the prosperity of the undertaking. The inherent defects of the system, and the modifications in plan and working which appear to me needful to introduce in order to remedy these drawbacks and to permit of greatly enhanced results, will receive attention and then by making comparison between the methods practised respectively at Comacchio and at Arcachon, I hope to be able, by utilizing the best features of the two systems, to outline a practical working scheme for the establishment of fish-farms in

the back-waters, salt-works, and salt marshes of our Indian littoral.

Comacchio lagoon will be found intensely interesting alike by pisciculturists and biologists, by students of the municipal or communal management of industries, and by the non-expert who merely wish to quit the beaten track and see a district where the din of the outside world is unheard, where habits and customs are little changed from what they were centuries ago. Such a visit I commend to any one passing through Venice with three or four days to spare, but so out-of-way is Comacchio that I had considerable trouble to find my way there. Although not more than 50 miles down the coast from Venice, the tourist agents scarcely knew it by name. The best way to reach the town appears to be to take train to Ferrara, a run of about $2\frac{1}{4}$ hours from Venice, and there to change to the steam tram that runs to Ostellato, a village near the western end of the lagoon. From this point, the voyager must trust to luck for a conveyance to Comacchio unless he arrives there at 4-30 P.M. when a ramshackle mail-cart connects with the train. If Venice be left by an early morning train, a couple of hours may be spared at Ferrara to visit the cathedral and the mediæval castle. Between Ferrara and Ostellato the tramway runs along one side of the main road, first skirting the Ferrara canal for some distance and then through a rich alluvial plain given over to the cultivation of beetroot and hemp. No actual vineyards are visible, but the rows of poplars skirting the road and demarcating the fields are connected by rich festoons of vines, heavily laden with grapes at the time of my visit.

At Ostellato, I had choice between a ricketty mail-cart and a nondescript closed vehicle with worn-out springs and a harness composed principally of string. This latter after considerable hesitation I chose and having deposited my courier within, I mounted the box with the driver, who beguiled the tedium of the journey by reciting verses from Petrarch and an account of his own adventures under Garibaldi during the war of Italian independence.

It was after 7 o'clock when we arrived at Comacchio, which to my surprise I found to be a town of several

thousand inhabitants, boasting a cathedral, several large churches and a quaint three-way bridge at the intersection of four canals.

Owing to its isolation scarcely any one can be found in the town capable of understanding either English or French, hence unless the visitor be conversant with Italian, it is necessary to engage the services of an interpreter when leaving Venice. In order to obtain permission to visit the fishing stations in the lagoon application should be made at the office of the Commune, where I am sure every assistance in obtaining a boat and a guide will be willingly given. The Communal officials will probably be able to arrange for a visit to the eel-curing establishment of the lessees of the fishery, who are at present Messrs. A. Cornia & Co.; if not, then a personal application to this firm will no doubt receive as courteous response as did my own. Among the points of interest which particularly deserve a visit, are the fishery station of San Carlo, a little to the west of the town, that of Cerilla in Valle Vacca, the port of Magnavacca, and one of the river-sluices, say that of San Alberto at the extreme south of the lagoon.

Description of the Lagoon.

The lagoon of Comacchio is a vast shallow salt-water lake, irregularly circular in outline, situated in the southern section of the delta of the Po. Along a portion of the northern side flows the river Volano, while the river Reno similarly bounds the southern extremity. On the west or landward aspect it is shut in by marshes and low-lying agricultural land, while on the east it is separated from the Adriatic by a long belt of sand dunes (technically termed *lido* in Italian) which extends from one river mouth to the other with breadth varying from two to three kilometres. The circumference of the lagoon is about 125 kilometres ($77\frac{1}{2}$ miles), whereof 9 are bounded by the Volano, 12 by the Reno, 74 by the semi-circular curve of the mainland on the western aspect, and 30 by the Lido.

In Coste's time the water-area amounted to about 40,000 hectares (98,844 acres), divided among 40 compartments or basins of varying dimensions known as valli (or *campi* in the Comacchio dialect); to-day by the

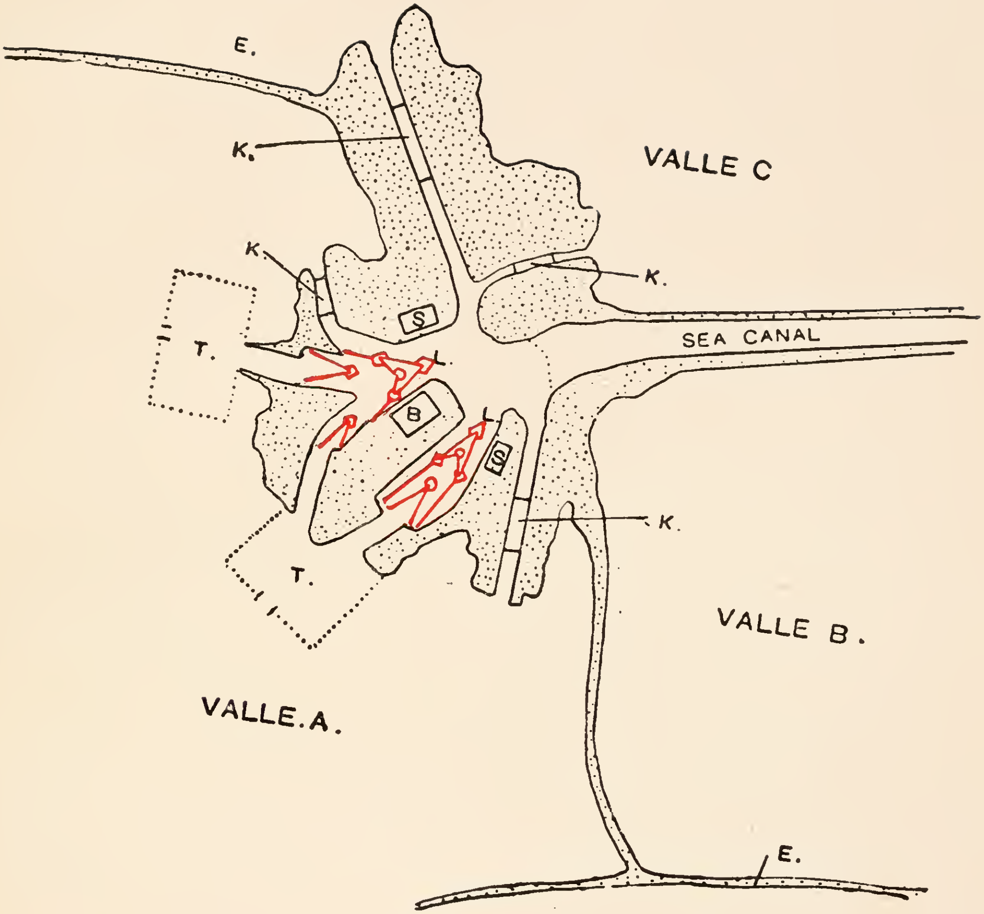

Fig. 4.—Plan of a Fishing Station in Comacchio Lagoon.

B. Fishermen's barracks.
E. Embankments separating the valli.
K. Lock in service-canal.
L. Lavoriero or labyrinth (shown in red).
T. Quadrangle of a Tressa.
S. Store-house.
(The portions above water level are indicated by dotted stippling).

reclamation of three of the shallowest and least valuable sections, there remain only 37 sub-lagoons or valli aggregating about 36,500 hectares (90,200 acres).

To every valle is apportioned at least one fishing station, where centre the oversight and working of the valle thus served. Here are situated the lavorieri or labyrinths employed to trap the mature fish, the barracks where lives the fattore of the valle with the company of fishermen and guards under his control, and the storehouses where are kept the live-chests required during the fishing season together with the materials needful for the upkeep of the labyrinth palisades.

The fishing stations are located usually at places where natural islets existed at the time when the respective embankments were constructed. To economize labour when forming the valli every advantage appears to have been taken of the occurrence of chains of sand banks and of islets—remnants in many cases of a sea-bar or lido. The most convenient islet in each valle embankment was chosen as the site of a fishing station and there were dug several short cross channels to connect the confined water of the valle within, with the ebb and flow of the sea-channel without. In the heart of this plexus of short canals, which radiate fanlike towards the water of the valle, lie the islets whereon the fishermen's barracks and the various store-houses are built, as may be readily understood by reference to text-figure 4. The principal canals are blocked against the passage of boats by the several series of converging palisades forming the labyrinths, so to overcome this difficulty, subsidiary narrow canals (service canals) are provided to give passage to boats between the valli which adjoin at these stations and between them and the feeder sea-channel. The service canals are provided with simple locks (Plate VII, figure 12, and text-figures 4 and 5) easily manipulated, whereby ready intercommunication is maintained while safeguarding the fish in the valli from escape.

As mentioned above the various valli or, as we may term them, "fish-farms" differ greatly in size, ranging from the immense Valle Mezzano of 17,407 hectares (43,016 acres) down to the tiny Valle Molino of 71 hectares (175½ acres). About 20 of these great fish-ponds may be reckoned to be of first-class rank in

regard to area and fish-rearing capability; the remainder are either so small or suffer from such disabilities as to be of minor importance.

The various sections are bounded and divided from each other partly by natural divisions consisting of natural tongues of land and chains of islands and sand banks, and for the rest by artificial earthwork dykes connecting the islands and miniature peninsulas into continuous embankments. Where necessary the foot of the dyke on one or both sides is strengthened with rows of stakes. The earthwork itself is the sandy mud from the bottom of the lagoon; there is generally a large admixture of broken shells in it and this is considered to have a beneficial effect in the consolidation of the rampart. The sedges and grasses which grow freely over the slopes are further useful factors in the work of consolidation.

The sand-bank peninsulas and chains of islands nearly all run in a direction north and south, roughly parallel with the present sea-coast. The best defined chain divides the lagoon into two almost equal parts. The western or inner half is again subdivided by a dyke into two distinct and very large fish-rearing valli, the Mezzano of 17,407 hectares and that of Fossadiporto of 2,701 hectares. The eastern or seaward half of the lagoon contains the remainder of the fish-farms, very numerous, very irregular in outline and often comparatively small. The depth of water in the valli is never great, it ranges generally between 3 and 6 feet but in times of drought large sections of the bottom become dry through the shrinkage of the water area.

All the valli are in more or less direct communication with the sea by means of canals opening from one of two sea-mouths traversing the Lido, that natural breakwater which protects the lagoon from the inroads of the sea. The principal sea-mouth, that called the Port of Magnavacca, cuts through the Lido almost midway between the embouchure of the Volano and the Reno. Its length is about 2 kilometres, by 40 metres (131·2 feet) wide, and $2\frac{1}{2}$ metres (8·2 feet) deep at mid-tide. The banks are heavily timbered and two wooden groynes or breakwaters defend the seaward end. This mouth feeds the whole of the fish-farms with sea-water, with

the exception of a few in the north-eastern section of the lagoon which are served from a small canal called Bocca del Bianco, a natural sea-channel through the Lido, scarcely 12 metres wide, not always active, and serving directly two valli only.

The channel of Magnavacca after traversing the Lido bifurcates; each branch almost at once begins to give off ramifying side branches at varying intervals each having the same breadth as the mother channel. Each of these subsidiary branches eventually divides into a fan of terminal channels opening into one or other of the several valli. Two of the main canals are of special importance—those which diverging from Magnavacca in the form of an immense V penetrate ultimately to the Mezzano Valle and are the only means of communication between this vast sheet of water and the sea. These two canals serve roughly to separate the eastern half of the lagoon into three divisions, a southern section of three principal valli, aggregating 6,548 hectares (16,181 acres), a northern set of valli with a superficies of 8,539 hectares (19,989 acres) and a median division embraced between the arms of the V with an area of 4,302 hectares (9,631 acres).

The Mezzano owing to the enormous area it covers is the most important fish-farm in the lagoon, being 75 kilometres ($46\frac{1}{2}$ miles) in circumference, 14 kilometres ($8\frac{3}{4}$ miles) from north to south and 18 (about $10\frac{1}{4}$ miles) from east to west. Unfortunately it is the most remote of all the valli from the sea, the shortest of the canals connecting it with the Port of Magnavacca being 10 kilometres long, while the southern sea-water sluices are as much as 14 kilometres distant from the sea.

Command of large supplies of river water is also as vital a necessity as communication with the sea both in order to reduce excessive salinity within the valli and as an integral factor in the annual stocking of the valli with new shoals of fry. To effect this, six sluices furnish communication between the river Volano and those valli which approach the right bank of this stream; in the same way the lagoon communicates at intervals along its southern border with the Reno by five similar sluices.

The town of Comacchio lies at the present day in the heart of the seaward half of the lagoon, upon a long

island connected with the mainland by a roadway carried along the summit of one of the principal dykes. Grouped round the town are the oldest of the valli, for the seaward section of the lagoon, possessing ready access to the sea, was naturally the scene of the initiation and gradual evolution of the complex system now existing.

To-day the town is 5 kilometres from the seacoast, but I am of opinion from the character of the northern portion of the lido or sea-bar that when Comacchio was founded it was not more than 3 kilometres from the sea.* At that time the valli now existing in the extreme north-east of the lagoon, those between and including Valle Volano and Valle Stefano, probably did not exist, the sea-bar certainly was considerably narrower and access between the lagoon within and the sea without was much more free that it now is—probably with a well-marked and free tidal flow renewing the water of the lagoon daily, making it a *laguna viva* or living lagoon such as is paralleled by the condition of that of Venice to-day. Now, the lagoon being dyked all round and with water not in ample and free tidal communication with the sea, it has become the type of a *laguna morte* or dead lagoon, in the language of Italian valli-culturists—an inland sea shut off from the Adriatic, save for the narrow sluices opening from each valle into the marine canals.

The information we possess concerning Comacchio does not antedate the 6th century, but there can be little doubt that the principles governing the present system of fish-farming were conceived and the foundations of valli-culture laid several centuries earlier. The system followed is in substance similar to that known to and practised by noble Romans shortly before the beginning of the Christian era as detailed by Pliny and other early writers; it is very probable that its introduction into the

* This conclusion receives confirmation from the fact stated by Feletti * that the seaward extension of the sea-coast south of the mouth of the Volano has been 20 metres in ten years. If we assign the founding of Comacchio to the 5th century—say 1,500 years ago, this would give an extension of 3,000 metres as against the 2,000 which I claim. But of course the rate of deposit is not and cannot be uniform and it is probable that the rate of deposit is rather more rapid now than some centuries ago, as the extension of cultivation and of drainage tends to make floods more violent and so bring down more sediment and so increase the rate of the formation of deltaic lands. (* "*Intorno all attuale salsedine della acque del Campo Trebba*," *etc.*, p. 3, Comacchio, 1909.)

Comacchio lagoon was due to Roman influence and owed its inception there to the enterprise of men familiar with the fish-pond culture of Rome and Naples.

We know little or nothing of its history during the middle ages; whoever ruled in Ferrara from time to time doubtless dominated the lagoon, this being the greatest of the feudal strongholds of the immediate neighbourhood. In the 16th century the fishery in the lagoon was one of the chief sources of revenue to the Este family, Dukes of Ferrara. In 1598 Pope Clement VIII dispossessed the Estes and seized both the Duchy and the Comacchio lagoon. The claim for compensation made by the Este family against the Papal Court stated their annual receipts from the fishery at 300,000 lire (Rs. 1,80,000) but this was probably an exaggeration. At this period, the end of the 16th century, the lagoon presented a very different appearance to what it does now. In spite of much extensive reclamation made of recent years the area at the period above named was considerably smaller. Then the greater portion of the Mezzano, now by far the largest of the lagoon fish-farms, did not exist as such. It was a marsh choked with reeds and rushes into which flowed the drainage of a great area of cultivated land lying to the westward; here this water stagnated, percolating slowly through the separating dykes into the adjoining valli. From its position as a vast marsh between the lagoon proper and the cultivated land it indeed derived its name *Mezzano* or middle.

In this condition the lagoon remained till Cardinal Palotta was appointed by the Papal Court as Governor of Ferrara in 1631. Finding the sea-channel from Magnavacca to Comacchio badly silted and capable neither of admitting a sufficiency of tidal water for the health and prosperity of the different valli nor of permitting easy navigation to Comacchio, he had the channel not only cleared and widened but extended beyond Comacchio sufficiently far to give access to the northern region of the Mezzano, a distance of 6 kilometres from the city. This canal, known to this day in its seaward section as the Canal Palotta, measures $6\frac{1}{2}$ to $7\frac{1}{2}$ yards wide with a depth of some 6 feet. By these means the whole of the Mezzano was brought under control and useless marshes were converted to fish-rearing purposes.

Cardinal Palotta is ranked as one of the greatest of Comacchio's benefactors and well may that be for under his enlightened guidance the fish-rearing establishment attained full development. On the completion of his schemes the lagoon had practically the same area and arrangement seen by Coste fifty years ago. Whether the conversion of the Mezzano marshes into a vast and very shallow fish-pond has been justified by experience is however doubtful, for since Palotta's time there have been repeated periods of great depression in the industry caused by excessive and wholesale mortality among the fish of the great ponds furthest removed from the sea; the Valle Mezzano in particular being the one most frequently the scene of frightful fish mortality.

With the exception of the sixteen years between 1708 and 1724 when the Austrian Government held possession, the lagoon remained under Papal Government from the end of the 16th century until the close of the 18th century when Buonaparte in 1797 seized it during his campaign against Venice. Being loot he could not remove to Paris, he wisely sold it to the Commune of Comacchio. The ensuing sixteen years are perhaps the most notable in the history of the establishment; they far exceeded in continuous prosperity any other cycle we know of for Pepoli * records that the average yearly revenue for these years amounted to no less a sum than 567,749 lire (Rs. 3,40,650); since then both the revenue and the annual catch of fish have suffered cycles of violent fluctuations. On the whole the condition and revenue of the lagoon were not satisfactory during the last seventy-five years of the 19th century. At present the lagoon as a fishery establishment, is enjoying a period of renewed prosperity due partly to climatic causes, partly to more careful and scientific management, and partly to the reclamation and utilization as agricultural land of large areas of the least productive fish-farms.

Principles and Details of the System.

The principles governing the system of fry capture and fish-rearing practised at Comacchio are essentially the same as those forming the basis of the Arcachon

* *Fide* Bullo, Piscicultura marina, part 1, p. 365, Padua 1891.

system; in both the aim is to utilize the natural instincts of certain species of fish in such manner as both to stock enclosed ponds automatically with an ample supply of fry at one season of the year and at another season to trap in quantity such fishes as have attained maturity and whom instinct leads to attempt to pass to the sea for spawning purposes.

The differences and modifications which we shall now describe are due in the main to the larger field of operations which is involved; the one deals with ponds of restricted area, the other with sections of an inland sea.

Apart from the matter of relative size, one of the most important divergences seen at Comacchio is the provision of separate openings in the encircling embankments of each pond or valle for the entry of the fry during ascent (*montée* or *montata*) and for the construction of pounds or labyrinth traps for the capture of the adult fish. This separation of function is rendered necessary owing to the great extent of the principal ponds and in order to gain full advantage from the freshening influence of the non-saline water of the rivers flowing along two sides of the lagoon.

All the chief ponds communicate on the one hand with these two rivers by means of massive sluices, and on the other with the sea by one or other of the branch canals arising from the sea-channels which traverse the lido at Magnavacca or Bocca del Bianco. It is the aim of this dual communication between the ponds and the sea on the one side and the ponds and the rivers on the other, to render possible the mechanical stocking and fishing of the various fish-farms and at the same time to introduce fresh supplies both of river and of sea-water to moderate the high salinity which otherwise would be caused by evaporation and generally to assist in maintaining healthy conditions within the lagoon.

(*a*) *The stocking of the Lagoon.*

To give entry to the fry of those fishes whose instinct leads them to enter river estuaries when very young, on 2nd February in each year, the sluices leading to the Reno and the Volano are opened, together with all those in the sea-canals leading to Magnavacca or the Bocca del Bianco. A temporary third channel, the Taglio del

Gobbino, is opened at the same time through the sand-banks of the Lido to provide direct communication between the sea and certain of the southern valli and carry thereto adequate supplies of sea-born fry. To further facilitate the entry of fry and to ensure a uniform distribution throughout the more remote valli as well as those fed directly from the river sluices and sea-canals, numerous gaps are cut in the dykes separating the valli from one another and in the banks of the sea-canals themselves. Every effort is directed to putting every valle in free and untrammelled communication with the rivers and the sea; to this end the sluices are opened, the canal banks cut and dividing embankments breached; all other duties yield to the vital necessity to obtain a large stock of fry.

During the period the lagoon is thrown open to the free influence of tidal flow, a distinct current is produced during the ebb, flowing outwards through the river sluices and through the sea-channels. As we have seen when discussing the Arcachon system, this outward current is the important factor in attracting the fry of eels, mullet and atherine smelts—the three species particularly desired at Comacchio—towards and into the lagoon as at this stage in their life the fry obey an instinct which leads them to swim against any sea-going current; when they once enter the lagoon they scatter and shew no immediate desire to undertake further journeyings.

The abundance of fry entering the ponds being a matter of the gravest anxiety to the authorities during the months of ascent, employés of the commune supervise the entrance of the shoals through the various sluices and gaps. From time to time these men assure themselves of the quality of the harvest. The method is a rough one, but answers sufficiently well; it consists of lowering bundles of brushwood into the entrance channels; these are periodically taken up and well shaken or beaten, an action which causes all the eel fry that have taken refuge in the interstices to fall out; according to the quantity thus obtained they gauge the abundance or scarcity of the run of fry.

The fish whose fry penetrate into the lagoon in this manner consist in the main of eels (*A. vulgaris*), smelts (*Atherina Boyeri*), gobies, mullet of several species; a

fair quantity of bass (*Labrax lupus*), soles and plaice also enter together with various crustaceans and molluscs. The young eels at the time when they enter estuaries are 6 to 7 centimetres in length and it is estimated that some 3,600 individuals go to a kilogram. The mullet fry are still smaller, 20,000 going to the kilo. The former attain maturity only after a residence of 4 to 5 years in the ponds when they should weigh from 4 to 5 lbs. each. During the period of ascent, February, March, and April, care is taken to prevent net-fishing off-the coast in the neighbourhood of the lagoon, but after the closing of the lagoon at the end of April or the beginning of May, a large quantity of young mullet are caught by means of fine-meshed nets in the shallows along the coast; this particular stock is kept separate from the general herd, being placed in special ponds.

When the inward migration of the young fishes diminishes to inconsiderable proportions, usually about the close of April, measures are taken to close all means of egress from the lagoon. The river sluices are shut, the gaps in the embankments are repaired and the mouths of the permanent passages leading from each valle to the adjoining sea-canal are closed by the construction of palisades of stakes, to which are bound tightly packed bundles of reeds, planted upright in the mud. These particular obstructions are termed *tresse*; they occupy a most important position in the working of a valle, for while they must be capable of impeding the escape of fish to the sea, they must allow tidal water to enter the otherwise closed ponds—a difficult proposition.

The openings closed by tressa-palisadings are restricted to those centres known as fishing stations where permanent passages are maintained either between each valle and one of the sea-canals or between adjacent valli. In general each valle has one fishery station, but some have more. Mezzano has 4, Campo and Ussanola 3, Cona has 4, Vacca has 2. From each of these stations, branch out towards the particular valle served, a number of short canals called *Covole* (text-figures 4 and 7) which have the function of reducing the tidal flow received from the main and wider sea-canal by dividing it into a number of smaller streams and thus discharging it into

a valle by several mouths instead of by a single large one. It is at the inner or valle mouth of a covola that the tressa palisading is erected. Usually it takes the form of a large rectangular enclosure projecting well out into the water of the valle. When constructed at the end of the stocking season, the palisading is complete on all sides except that facing the covola. A simpler form sometimes used is where the tressa has a V-shaped form, being constructed of two palisades built out from the mouth of a covola and inclined inwards or towards one another so that they eventually meet in an acute angle.

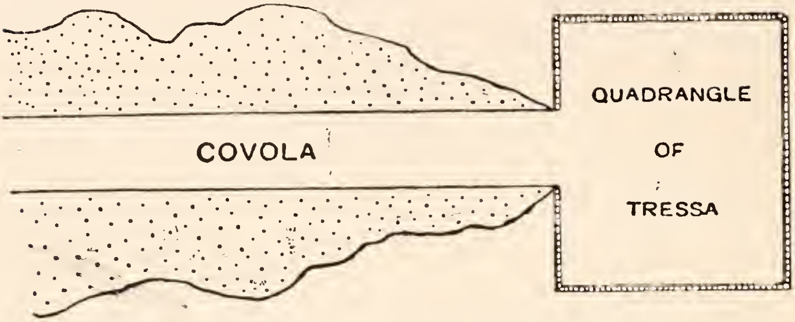

Fig. 5.—Plan of a true tressa.

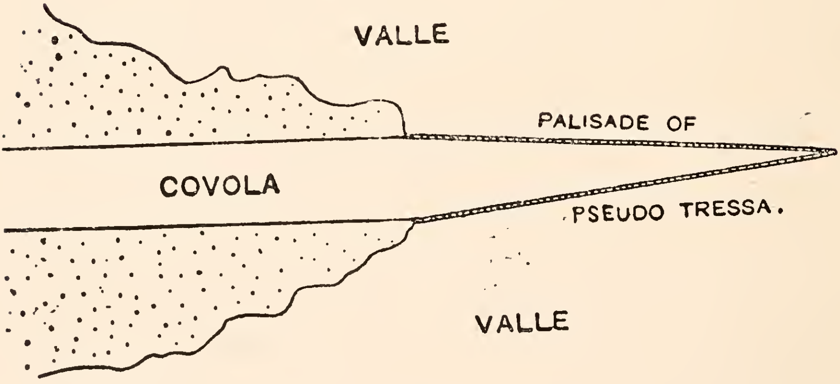

Fig. 6.—Plan of a pseudo tressa.
Earthwork shown by dotted shading.

Both these forms are designed to afford a very large surface for percolation, just as the screens used in fresh

water fish-culture should be made several times larger than the sectional area of the stream they intercept, in order to allow for loss through the clogging of some of the meshes and still be able to pass the full quantity of water without difficulty.

The reed component in the tressa wall is the one essential to the proper performance of this function; the other parts are designed to give necessary support. The reeds are first tied into handy-sized bundles and then built up around the mouth of the covola or passage into a very tighty compacted palisade six inches in thickness. The bundles are made sufficiently long to admit of being firmly imbedded at the lower ends in the mud, while the upper project 2 to 2½ feet above the normal level of the lagoon. The method of supporting these bundles by a frame work of upright stakes and horizontal bars may readily be understood by examination of plates V and VI, figures 7 to 10. As seen in these photographs these reed palisades vary in thickness and in the strength of their supporting frames according to the duties they have to perform; in the majority the reed hedge is staked on both sides (fig. 10, pl. VI), in others a single lateral row of supports suffices.

When first built a tressa by its peculiar form offers a very large percolation surface and the sea-flood welling through the feeder canals passes rapidly through the reed hedge into the lagoon. Unfortunately the spores of algæ and the swimming larvæ of various zoophytes and other sedentary marine animals are likewise borne up by the tide and settle upon the palisade; here they find conditions extremely favourable for their growth and in a short time they fill the interstices so completely that the walls of the tressa become all but impermeable; the volume of water passing through becomes so reduced that it may be said to have no appreciable influence upon the salinity of the lagoon thereby contributing largely to the gravest danger to which Comacchio valliculture is exposed as we shall presently—(see p. 44).

When once the *tresse* have been built and the gaps in the embankments repaired, work becomes restricted to surveillance and the cutting and preparation of the reeds and other materials that will be necessary when the fishing season begins in autumn.

(*b*) *Method of Fishing the Lagoon-ponds.*

The capture of the fishes reared in the lagoons is on a scale of such magnitude that ordinary fishing methods do not suffice ; 1,000 tons of fish have often been taken in a single season. The fishing period is usually confined to the months of October, November, and December, when the instinct of the confined fishes, of the adult eels in particular, is insistent for migration to the sea. Last year the season opened exceptionally early having already been some weeks in full swing at the time of my visit on 29th September. The catadromic instinct seems indeed to be developed considerably earlier in the year in eels living in the Comacchio lagoon than in those of the adjoining Venetian lagoons, where the migratory instinct is developed in eels at the end of autumn as in the case of these fishes in French and English streams. Samaritani states that long experience and many observations have demonstrated that in the Comacchio lagoon, where the water is always very different in density from that of the sea, especially during the heats of summer, shoals of adult eels crowd around the tressa palisades sometimes as early as the months of June and July attracted thereto by the percolation of sea-water through the hedge of reeds. Indeed with such energy do they attempt the passage of the barrier that nets have to be placed in the channel behind the tressa and it appears probable that many do actually escape. As to the mullet, their instinct to make for the sea begins to be active early in August.*

Usually the commencement of the great fishing season is postponed till the end of September when high spring tides and gales from the eastward may be expected—two of the principal factors in inducing a heavy run of fish into the fish-pounds. Several weeks prior to what is termed the *taglio delle valli*, the removal of a short section in each tressa palisade to form an aperture of restricted width to permit the escape seawards of the adult fish within the ponds, every fishing station throughout the lagoon becomes the scene of great activity. The whole staff engages upon the

* G. Samaritani. Provvedimenti necessari nella Laguna di Comacchio, p. 18. Venice, 1899.

preparation of the materials required for the construction of the great fish-pounds named labyrinths by Coste, in which the fish are to be collected upon their escape from the valle. This work having been completed at the time of my visit to the lagoon, I shall fall back in the next paragraph upon Coste for a description rendered in his usual vivid manner, translating freely :—

" Every valle is transformed at this time into a combined workshop of wicker working and carpentry. All the employés are there occupied, some in binding together bundles of reeds (*Arundo phragmites*) into sections destined to form the walls of the labyrinths whereinto the play of tidal water will attract the fish, the others in preparing the posts which will support these permeable partitions.

" The bundles of reeds are made up into short hurdle or screen-shaped sections about 4 feet long by some 7 feet high ; by overlapping these sections and by binding them tightly together they are enabled to form lengths of whatever extent may be desired while by superposing them like the leaves of book they are able to make them of thickness suitable for the special service they are required to fulfil. Each section is strengthened on one surface with two transverse parallel rows of poles (or battens) which extend from one extremity to the other, and vertically with two strong posts which project beyond the lower margin in such manner as to be capable of being driven into the earth.

" When they have completed a sufficient number of these sections, they begin to place them in position, that is to say, they commence to organize the labyrinths whose construction although very simple exacts however so much precision and care that it is entrusted only to the most experienced of the vallanti and sometimes even to an engineer.* They adjust several of the reed sections end to end and thus form palisades of length proportioned to the particular requirement.

Then making two great lengths of this palisading, they plant them vertically in one of the passages at the extremity of one of the tidal channels leading from the Palotta Canal. The anterior extremity of one of the palisades is embedded in the left bank, the corresponding extremity of the other against the right bank. These two walls being thus secured in front—that is to say towards the end of the channel where it enters the lagoon—the posterior extremities—those directed towards the sea—are brought together in the centre of the channel in such a way as to press against one another but lightly. In this way two palisades thus disposed form a V-shaped angle whereof the opening looks towards the lagoon while the vertex is directed towards the (tidal) current which comes from the Adriatic.

" Matters being in this state and without changing the disposition which I have just described, the work people drive into the soil the posts with which the palisades are armed until the lower edges of these partitions are pressed sufficiently deeply into the mud that

* For some years past the Administration have employed a highly skilled engineer upon their permanent staff.

nothing can pass beneath. But as the mouths of the canals where they construct these works are constructed in such a fashion as to have only 3 to 4 feet of depth, it follows that the bundles thus implanted and which are 6 to 7 feet high, project above the surface (of the water) two feet at least and sometimes even 3 feet.

" If a fish which has left the lagoon passes now into one of the mouths of the Palotta canal in order to escape to the Adriatic, it will be compulsorily conducted to the extremity of the acute angle where the two palisades touch without being attached to one another. There if it makes an effort to pass beyond, these two walls yielding slightly to the pressure, will open and then spring back into position after the fish has passed between, closing the issue in such manner that it becomes impossible for the fish to return through it. But it would be free to gain the sea did it not find itself within a second compartment of the labyrinth where it thenceforward remains a permanent prisoner. On passing through the narrow opening at the angle of the first barrier, it finds itself in a heart-shaped chamber (*botteghino*)* attached at its base to the outer surface of the two first palisades in such a way that the acute angle of the latter barriers projects into its interior. This small chamber, whose walls, formed also of fascines of reeds, are supported exteriorly with stakes in similar manner to the walls of the whole labyrinth, has also a narrow slit-opening at its apex which permits the prisoners to advance into the more distant chambers. Beyond the small *botteghino* are found two other palisades disposed in an angle of which the base, in the manner of those first described, includes the whole width of the canal and whereof the apex, directed against the tidal current, gives ingress by means of a narrow opening into a second small chamber into which the fish eventually pass after traversing the space bounded by the second series of palisades. Arrived in this second confined space (*baldresca*) not only are the fish unable to retrace their way but not finding any opening at the further extremity, as the walls are continuous they remain there captive if a mullet, a sole, a bass or a sparoid, for these species are not lithe enough to traverse the small openings in the barrier; if on the contrary it be an eel, it insinuates its head or its tail between the reeds and with the help of the vigorous movements of which it is capable it slips through the walls of its prison leaving behind it all those of its companions whose form is not adapted to such muscular exercise. But this exhibition of skill and strength does not help it to freedom. It falls into yet another triangular space, vestibule of its definitive prison, where after wandering a longer or shorter time without succeeding in traversing the wall of which the thickness and strength have been specially calculated to resist its endeavours, it finds only three exits similar to those through which it has already passed and which are situated at the angles of the triangular space where all its efforts to escape have been checkmated. Finding no other passages practicable and tired of the struggle, it

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* The shape of this first small chamber (*botteghino*) in those fishing stations which I inspected is actually diamond-shaped. The only heart-shaped chamber in the labyrinths as now constructed is the *baldresca* where the mullet are separated from the eels.

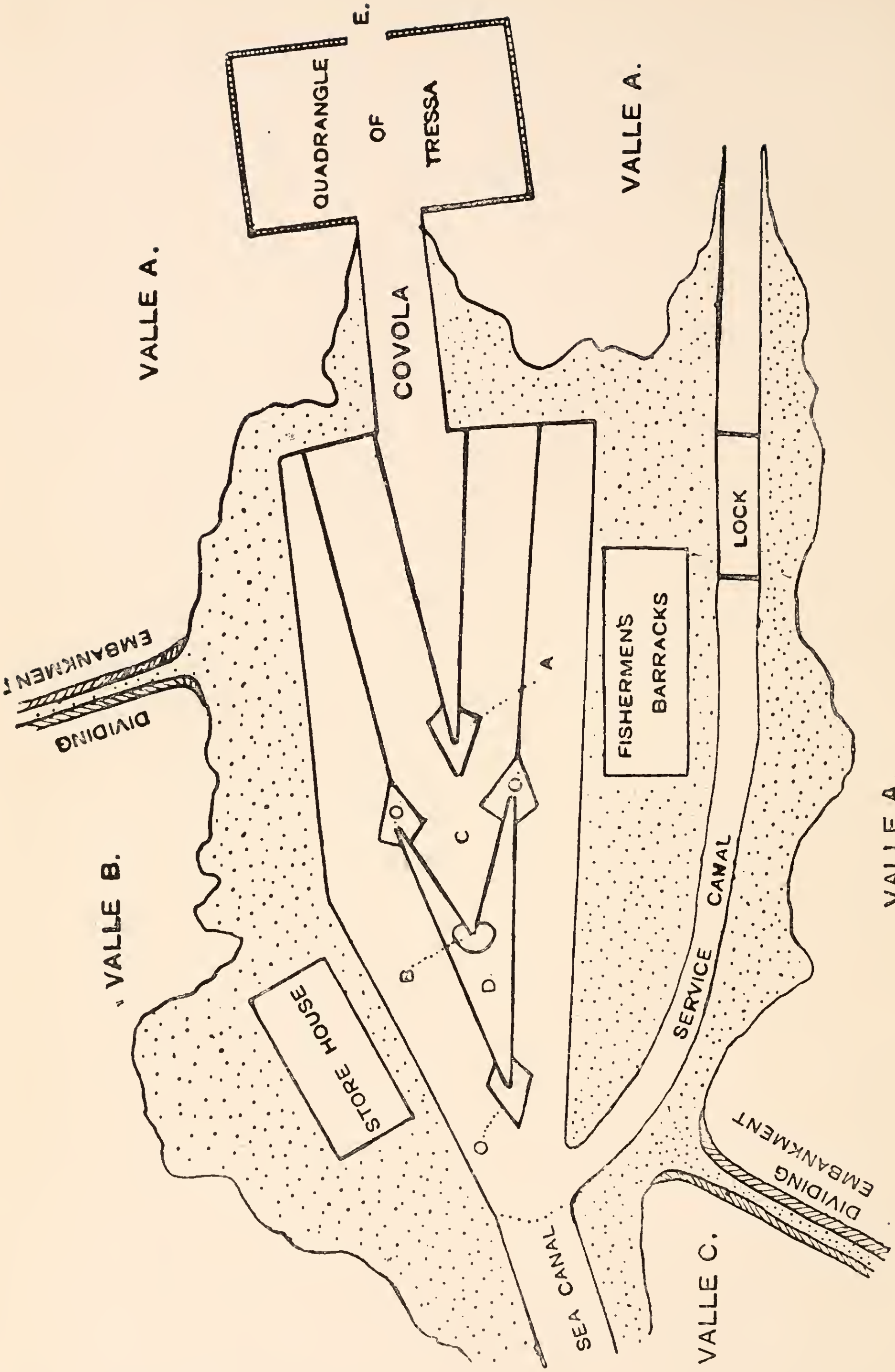

FIG. 7.—PLAN OF A LAVORIERO OR LABYRINTH, SHOWING ITS ARRANGEMENT AND ITS RELATION TO THE OTHER PARTS OF A FISHING STATION.

A. Botteghino. B. Baldresca. C. Coloura vivo.
D. Cogolara. O. Otéli or eel-trap chambers.
E. Opening in Tressa palisade to give free communication with the valle served by this labyrinth. Land and embankments shown by dotted shading.

finishes by passing through one of the openings available. But. behind each of these issues, a final chamber with walls as impassable as those of the large triangular space it has quitted, yields it into the hands of the fishermen.

"These ingenious devices which the Adriatic currents permit of execution, are not therefore limited to the attraction of fish from the lagoon into the sea-channels; they assist as well in the separation of the species just as the mechanism of certain factories separates the material which is the object of their operations. The art of fishing is elevated here to the height of an industry which reposes on principles of which the application conducts to a termination contemplated in advance and always with identical results. This industry marks the place where the crop shall be gathered and each species proceeds to the store compartment which is assigned to it; there is only to open a sluice in order to operate this marvel which during the space of three months collects yearly the matured harvest of the lagoon."

The construction of a fishing labyrinth, termed *lavoriero* at Comacchio, will be readily understood from the foregoing description read in conjunction with the diagram here inserted (fig. 7).

A fishing labyrinth divested of detail may be described in short as an arrangement of vertical walls made of two or of three thicknesses of reed screens embedded in the bottom of a sea-channel and supported by vertical posts and horizontal poles, the whole arrangement forming a succession of angular enclosures, each having the open base turned towards the passage (*covola*) leading to the lagoon, and the apex towards the sea. The fish enter the main or second enclosure, the lavoriero proper, through a narrow vertical opening cunningly contrived at the apex of the first series of palisades. When in turn the fish attempt to leave this principal chamber, in passing out the species separate automatically in such manner that the mullet are imprisoned in a small round or heart-shaped pound, called *baldresca*, at the apex of the palisades of the main enclosure, while the eels pass through the comparatively thin wall of the baldresca into a terminal triangular enclosure having a small chamber or *otele* at each of its angles (pl. V., fig 8, and pl. VI., figs. 9 and 10). The walls of the *oteli* as well as those of the large enclosure whereof they form part, are constructed in a most massive manner; the reed screen, composed of a great number of layers of reed fascines, is usually from 7 to 8 inches thick supported by stout piles and secured by strong horizontal baulks of timber on the exterior as seen in pl. V., fig. 7, and pl. VI., fig. 10. From the final traps

the fish are lifted by means of a dip-net, and placed in great spherical wicker store-pots till removal to the preserving factory.

This so-called fishing of the lagoon continues usually during a period of three months. The amount of fish collected each day in the various pounds varies with the state of the weather. Large catches occur only on moonless or overcast nights; when storms from seaward, especially the *levante-sirocco* blowing from E.S.E., coincide with the occurrence of such black nights, the quantity of fish that accumulates in the lavoriero is often so exceedingly great that the inner pounds become choked with a solid mass of struggling fish. Bonaveri* records that after one such night (4th October 1697), 322,520 kilogrammes of fish were taken from the pounds, as much as 64,504 kilos being yielded by one valle alone. Quantities so vast are inconvenient to handle, so whenever the workers find the fish accumulating too quickly in the enclosures, they light bonfires at the sides of the tressa and this has the effect of checking the migration temporarily.

The reason for the great rush of fish into the lavorieri during a tempest is that when this is from the eastward it raises the water unusually high in the tidal-canals and thus induces an increased flow of water through the palisade barriers into the lagoon—a call which the adult eel and mullet hear and act upon immediately. Occasionally at these times, the storm heaps up so great a quantity of water in the canals, as to entail such pressure upon the walls of the labyrinths as to compromise their stability. To avoid this, although the proceeding tells against the success of the day's fishing, it becomes necessary to stop the flow of water through the palisades into the lagoon by shutting certain sluice gates which are provided for this purpose either in the covole or in the sea-canals themselves.

It is obvious that during the summer season when the walls of the tresse are continuous, and also during the fishing season when, although the tresse are open, the terminal (inner) mouths of the sea-canals are completely obstructed by the palisades of the labyrinths, special means must be provided to permit the employés and

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* Storia della Citta di Comacchio, 1761.

watchers to move freely in their boats from valle to valle. Accordingly we find at almost every fishing station, a narrow service-canal passing round at one side giving access to the valle from the feeder canal from the sea. In other places a similar narrow boat canal cuts the separating embankment between adjoining valli. To prevent the escape of fish by way of these service-canals, wooden locks of the simplest description are installed in convenient positions in their course. Figure 12, pl. VII., depicts clearly the appearance and arrangement of one of these locks. The lock "gates" are stoutly built wooden shutters extending the width of the cut, the ends and lower edge fitting into wooden grooves in the wood frame built into the bank and bottom of the channel. The lower edge of the lock-shutter is shorter than the upper to facilitate removal and replacement in the retaining grooves.

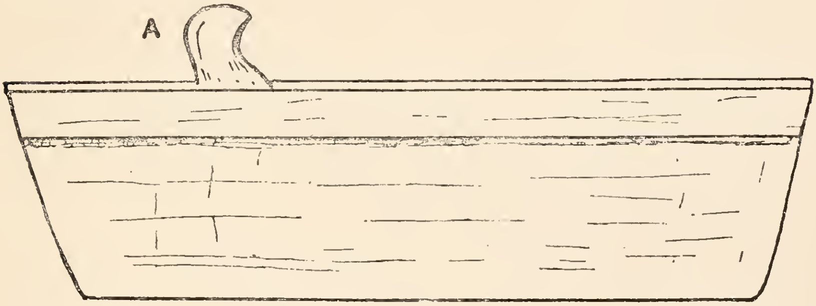

Fig. 8.—Diagram of wooden shutter used as a lockgate on the service-canal between a sea-canal and a valle.

A, Handle by which it is pulled up when the lock is to be opened.

Cycles of Bad Seasons; Causes and Suggested Remedies.

From time to time in spite of the great store of empirical knowledge gained from centuries of struggle, there occur disasters in this industry which impair its prosperity for a series of years. During the past century no less than six years are recorded as marked by excessive loss or mortality of fish, entailing a succession of unremunerative fishing seasons varying in degree according to the severity of the initial cause. It is probable, I believe, for the reasons to be stated later, that these cycles of disaster have tended to occur at shorter intervals and with great intensity since the Mezzano was

added to the fishery system in the middle of the 17th century; at no time however can this lagoon system have been immune since the period when it ceased to be a *laguna viva*—one wherein the sea daily ebbed and flowed freely throughout its whole extent. Blizzards from the Alps, exceptional floods in the rivers bounding the lagoon, intensely hot and dry summers—these are the three factors which are recognized as the principal causes of seasons of failure. For example, in 1711 a tempest of such intensely cold wind descended upon the lagoon that the fish died in myriads. This followed upon other losses in 1705 and 1709 caused by flood irruption of the adjoining rivers, whereby the dykes and tresse were submerged, allowing a great proportion of the imprisoned fish, young as well as mature, to escape to the sea.

Again, in the years 1718 and 1719 the heats of summer were so intense and long-continued that a great portion of the lagoon dried up and immense deposits of salt formed upon the bottom. Bonaveri states (*loc. cit.*) that salt to a value of over 18,000 scudi was collected. Owing to the immense amount of evaporation in these years the water that remained in the deeper sections became so highly saline that widespread mortality resulted among the fishes.

These disasters were exactly paralleled in the course of last century. In 1825, 1834, 1890, 1891, the summers were abnormally warm and as a result of active evaporation over the 40,000 hectares of shallow ponds the resultant high salinity of the water entailed enormous loss among all ages and species of the fish in most of of the ponds in the lagoon. In 1890 the seaward flight of the fish into the labyrinths was a veritable stampede and disastrous in proportion. The catch surpassed a million kilogrammes (say, 1,000 tons) in great part composed of minute and immature fish such as required a sojourn of several years longer in the ponds to attain a proper size. In the pounds of a single valle, that of Vacca, 100,000 kilos of fish were taken, while Valle Fossadiporto gave half this quantity within a few days. Much of the fish taken in the labyrinths was so tiny that the greater part after being placed in the great wicker store-baskets passed easily through the interstices and so escaped to the sea.

In the succeeding year there was a similar scarcity of rain, and the inimical conditions being intensified the slaughter of 1890 was repeated in those ponds which had been fortunate in escaping the dangers of that year. As a direct result of the excessive mortality characterising 1890-1891, the catch of fish during the ensuing seven years was abnormally poor and the Commune lost over a million lire (Rs. 600,000) on the working of the lagoon during this period—a large sum for a town whose prosperity is dependent almost entirely upon the produce of this fishery.

The enormous loss entailed by the winter storm of 1711, was repeated in 1850, entailing a series of miserable harvests during the next cycle of 7 years, while the floods of 1705 and 1709 had their counterparts in 1859 and 1862, when the Reno burst its banks and flooded the lagoon, liberating multitudes of immature fish and causing the fisheries of 1863-1865 to be among the poorest on record.

The following table given by Samaritani, * to whom I am indebted for the majority of the figures above quoted, shows clearly the fluctuations in the average catch during alternating cycles of prosperity and poverty :—

Period.	Number of years in cycle.	Catch of eels and mullet.				Remarks.
		In the first year of each period.	In the last year of each period.	Total for each period.	Annual average for each period.	
		kilos.	kilos.	kilos.	kilos.	
1798-1824	27	894,168	1,245,163	29,579,327	1,095,530	
1825-1838	14	487,977	585,207	6,293,110	449,508	Great mortality due to high salinity.
1839-1849	11	761,632	682,447	7,222,767	656,615	A winter storm in 1850 caused much mortality.
1850-1857	8	571,290	484,610	3,567,023	445,878	
1858-1860	3	613,548	715,509	1,974,783	658,261	Lagoon flooded from Reno in 1859 and 1860.
1861-1868	8	455,908	543,265	4,183,121	522,890	
1869-1890	22	639,060	1,024,257	19,915,987	905,272	High salinity in 1890—1891 caused great losses.
1891-1898	8	365,028	444,233	3,498,077	437,260	

* *Loc. cit.*, p. 7.

Besides the three main causes which periodically entail heavy losses on the valliculturists of Comacchio, there are several others which are either subsidiary and intensifying in their influence or which may be limited in their evil influence to certain sections of the lagoon. Of those latter Dr. E. Feletti mentions * an instance of one valle (Trebba) where percolation through the embankment dividing it from reclaimed land lying at a lower horizon, dangerously reduced the level of the water within, so producing a strong indraft of water from the maritime canal, which had the effect of causing a stampede of fishes into the labyrinths. Another cause of loss he traces to the liberation of poisonous gas (sulphuretted hydrogen) from the bed of the various chambers of the labyrinths, when from any cause the fish crowd in in excessive multitudes. Probably this is more or less true and the remedy is obvious that these passages should be cleaned out periodically and mud foul with accumulated organic matter removed. I would point out however that the mere disturbance of a mud bottom, apart altogether from any liberation of asphyxiating gases, is enough to kill many species of fish, mullet in particular. And whenever the labyrinths are choked with fish jostling one another and burrowing excitedly in the mud of the passages, this danger must arise. The factor of poisonous gas will certainly also be present under such circumstances, and this in combination with mud in suspension may cause a great proportion of the fish to die before it is possible to remove them from the pounds.

Floods may be guarded against by raising and strengthening the protecting embankments, and loss by percolation implies faulty workmanship. Frost and blizzards again are to be fought and their ill effects minimized by recourse to the device of excavating deep pits and channels in suitable places in the ponds, whereinto the fish may retreat when necessary. Bullo † mentions that these *refuge-canals* (*canale raccoglitore*) were first employed in 1863 and that experience has

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* "*Intorno all attuale salsedine della acque del Campo Trebba, ed alla moria di anguille nelle sue Covole*"; Comacchio, 1909.

† *Loc. cit.*, p. 406.

proved them to possess the greatest efficacy in protecting the fish from the harmful influence of winter storms. These refuges are always dug upon the windward side of a valle.

Apart from the intermittent factors which from time to time work havoc on a grand scale there appear to be a number of causes at work tending towards a gradual deterioration of the lagoon as a fish-rearing establishment. Fifteen centuries and more have elapsed since man began to build dykes to limit the free access of the sea to this great river backwater and to hold up water in the marshes of this delta. The passage of a period of this length, short though it be in geological history, is long enough to produce effects of importance under the conditions found at Comacchio. Deltaic accumulations may be slow in certain cases, but the change of estuarine swamps into low alluvial land is none the less inevitable. Thus we find that the depth of water in the inner sections of the lagoon, those margining the western shore, is gradually becoming less, as silt brought down during rains by the channels that drain the adjoining land, gradually accumulates upon the bottom. As a consequence the water capacity of these sections becomes reduced and when an unusually hot and dry summer supervenes, the consequent loss of water due to evaporation entails much more serious results than in former times—with a reduced volume of water at the beginning of the season, evaporation produces a salinity much higher than it would, were the original volume greater. So far has this silting of portions of the landward sections proceeded, that extensive reclamations have been made. Valle Gallare and Valle Volle, two of the largest valli after Mezzano, have been wholly reclaimed since Coste's visit in the middle of last century and extensive sections of the Mezzano and of Fossadiporto have also been turned into agricultural land within recent years.

Supplies of fresh water to correct the tendency of the enclosed waters to acquire too great a degree of salinity, are in the main derived from the two rivers bordering the lagoon, the Reno and the Volano. These unfortunately contribute less water than in former days, partly because increased cultivation in their basins takes up greater

quantity and so reduces the flow, and partly because the reclamations effected have entailed the loss of certain of the old sluices. This latter cause has operated in a specially adverse manner upon Valle Mezzano, the greatest section in the lagoon, for to-day it possesses but a single sluice admitting water from the river Reno instead of the three it once had.

While the fact cannot be disputed that the evils which result from certain defects in the present physical condition of the lagoon may be mitigated in large part if freer communication be established between the lagoon and the sea and if larger supplies of river water can be made available, the methods of so doing have been the subject of much controversy. The present is not the place to discuss the details of the arguments, as their interest and bearing are almost entirely local and special to the conditions of this particular lagoon. Additional river sluices and better regulation of those existing are among the most obvious remedies, but the river supplies are limited because of several considerations, some of which have been alluded to above, and permanent relief can only be obtained if the supply of sea-water be enormously increased. At present the lagoon is virtually cut off from free access to the sea during the period from May to the end of January. From May to September, the massive palisades of the tresse form all but impermeable obstacles, while during the fishing season between September and January the equally massive walls of the labyrinths offer as effective barriers to the tidal flow. Besides, what is gained by the lagoon during the flow is lost in large measure during the ebb. Either some radical alteration must be made in the methods of penning in and of trapping the fish, whereby the various barriers may permit free flow and ebb at least during the dry season, when evaporation is intense—a proposition no one has solved yet, or else means must be adopted to greatly increase the quantity of water brought in by the flood and then to prevent its reflux. The difficulty of passing sufficient water in during flood-tide by means of the restricted channels which alone are available is, however, practically impossible so long as the present method of constructing labyrinths and tresse is followed.

Bullo has suggested the destruction of the dykes separating the smaller seaward valli in order to form a huge reservoir, whence sea-water might be passed into the great landward valli. Samaritani, an engineer whose practical knowledge of the conditions are unrivalled, traverses the efficacy of this latter proposal pointing out that, as the evil to be averted is a rise in the salinity of the lagoon water, admission of sea-water is much less efficacious than that of fresh water.

Several of the best informed experts upon valliculture believe the conditions now existing in the lagoon and in the lands bordering it to be such that it is advisable to reclaim and give to agricultural purposes the whole or the greater part of the lagoon. Samaritani gives figures * based upon the results of reclamations already effected to demonstrate that this step would prove much more profitable to the communal authorities than to utilize the lagoon for fish-farming.

Elsewhere † he suggests as a less radical measure that, failing the adoption of a scheme for the total reclamation of the lagoon, great benefit would result to the remainder, if the less remunerative sections be reclaimed. If such were to be done, the area of the lagoon might then be so reduced that the river sluices now existing would be capable of supplying sweet water in sufficient volume to keep the remaining ponds at a suitable level and of a salinity agreeable to the fishes inhabiting them.

The Disposal and Curing of the Products.

An average taken over a period of 86 years in last century shows the annual catch of eels and mullet to be ‡ :—

Eels	695,818 kilos.
Mullet	78,431 ,,

Besides these a variable amount of less important fish, chiefly smelts and gobies, are caught and disposed of.

* *Fide* Bullo, *loc. cit.*, p. 365 *et seq.*
† Provvedimenti necessari, etc., p. 96.
‡ Samaritani, quoted by Bullo, *loc. cit.*, p. 366.

In a good year about 90,000 kilos of smelts may be taken and 2,500 to 3,000 kilos of gobies. *

Fully two-thirds of the eels and smelts are cooked and preserved in vinegar—marinated. The rest is sold fresh, except for special orders and under exceptional conditions of superabundance, when such large quantities are caught as exceed the resources of the marinating factory and of the receptacles for live storage.

Under present arrangements the whole produce of the lagoon is leased out by the Valli administration for a term of years, eight in the contract now running. Under the terms of this agreement the Commune, as the owners of the fishery, retain full control of the fish farms, employing their own permanent staff upon all the necessary duties, including that of collecting the fish. The lessees have nothing to do directly with the working and administration of the Valli, the administration supplying loads of fish as caught from day to day during the season at the lessees' factory.

At the time of my visit the lease of the produce was held by Messrs. Anselmo Cornia & Co., and Signor Cornia was kind enough personally to conduct me over his works and to explain fully the processes in operation. The factory is new and most conveniently designed. A canal runs along the rear with sidings branching into the building itself. In this way, the loads of fish are brought by boats without handling or delay right into the the hands of the workpeople.

I should here premise that the method of curing is limited almost entirely to the marination of eels and smelts, a process said † to have been invented (more probably improved) by Count de Bonneval, a French soldier of fortune, who commanded the Austrian troops who seized Comacchio in 1708 and who remained there for some years in charge of the garrison. Bonneval appears to have been a man of versatile talents and keen to do his utmost to advance the prosperity of the locality under his charge.

At the time of my inspection of Messrs. Cornia's factory, work was in full swing. A flat had just come in

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* Gobin, La Pisciculture en eaux salées, p. 212, Paris 1891.

† Bellini, La Laguna di Comacchio otti il dominio della Corte di Vienna, p. 10, Venice 1908.

filled with a writhing mass of thousands of eels all in the characteristic livery assumed when they are fully adult and ready for their catadromic migration. The boat lay in a little basin at one end of the heading room wherein were a number of "headers" seated before wooden blocks and each surrounded by several baskets. The eels in the boat were scooped up by means of landing nets, filled into baskets, and distributed among the headers whose operations consisted in chopping off the head of the still living fish and dividing the body at intervals so as to give lengths of about $4\frac{1}{2}''$ to each. Only at alternate intervals was the body cut right through; at the other points it was merely nicked deeply. This allows the halves of each double section to be readily folded upon themselves at the joint made by the deep nick at mid-length. As the men work they sort the pieces as they go, flinging them as cut into one or other of the baskets disposed within their reach, according to the size and quality of each section. Thus the stout sections from the thick portion of the larger fish go into one basket, the thin tail sections into another and a third will take those of fish of inferior size. The heads are considered as offal and are sold by the heap to the workers and local people at a trifling price.

As the baskets are filled with the severed sections, they are carried to the roasting room, where they are first spitted and then cooked before great fires laid in open fire-places. This roasting room extends the full width of the building; the fires, eight in number, occupy the whole of one side while along the side opposite are the spitting tables. The floor-space between the fires and the spitting tables is occupied with wooden racks on which the filled spits rest before and after roasting.

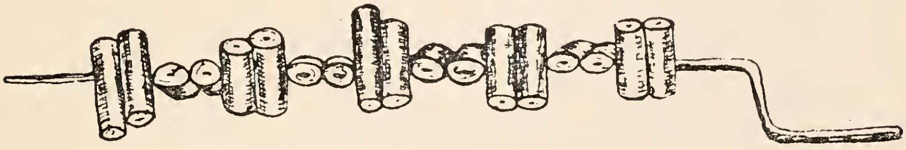

FIG. 9.—EEL-ROASTING SPIT SHOWING METHOD OF CHARGING WITH DOUBLE LENGTHS OF EEL-SECTIONS.

The spits upon which the double sections of fish are transfixed are iron rods about 7 feet in length provided

with an L-shaped handle at one end, so that when the rod is suspended upon a bracket at either side of the fire-place it may be turned or rotated by hand. As shown in text-fig. 9 the alternate pairs of eel sections are roughly arranged with their lengths at right angles to one another with a view to effect thorough cooking by a free exposure of the maximum surface. Eight of these spits are suspended on brackets before each fire, the whole number being arranged in a single vertical row. The four upper spits are tended by one woman, the four lower by a second ; both stand at the right-hand side of the fire-place, as the handles are all placed on that side. These two workers attend solely to the roasting of the fish—to the proper rotation of the spits. On the left of the fire other women see to the placing and removal of the spits. The fresh spits with the raw fish are placed on the upper brackets ; the lower rows get the greater heat and as they are completed and removed those above are moved down to occupy their places. The spits with cooked fish when removed from the fires are hung on the racks in the middle of the room to cool awhile before other workers strip the fish from them. Wood fires are used, laid on a flat open hearthstone. They are well supplied with fuel and are kept blazing furiously, giving out an intense heat. As the fish roast before the fires, a considerable quantity of oil oozes out. This falls into a sloping gutter in front of the hearth and flows along it into an underground oil-tank or collecting reservoir. Some further oil is also collected from the spits as they cool on the racks each of which is furnished with a wooden trough at its base to catch the oil drippings. The oil thus collected during the cooking of the eels is employed in the frying of smelts. When the roasted eels have cooled sufficiently, they are stripped from the spits and arranged neatly in circular shallow baskets which are then carried outside and laid in rows in the shade of a wide verandah where they are allowed to cool thoroughly before further handling. Considerable importance is attached to this item in preparation.

When quite cool the fish are carried to the packing room where the sections are neatly packed in wooden barrels and kegs. The lower layers are packed fairly

tightly, the upper ones rather less so; when full the barrels are headed up, and spiced vinegar containing a little salt is poured in through the bung. The barrels are left to stand thus for some time, additional vinegar being added if necessary to completely fill the barrel, when the time comes to close the bung. With proper packing 12 litres of vinegar are calculated to suffice to marinate 13 kilos of eels while half a kilogram of salt is the amount added to each 4 litres of vinegar.

The barrels and kegs employed are made on the premises. On an average about 22,000 are required for the year's pack. The great majority of the marinated eels are put up in four sizes of barrels containing respectively 15, 25, 35 and 55 kilos of fish. Austria and South Germany are by far the principal customers and Signor Cornia informed me that the value of the export of this product from Comacchio to these countries may be reckoned 200,000 lire and 150,000 respectively. Small quantities also go to France and Russia. During the middle ages these kegs strapped upon pack horses must have been familiar objects to travellers on the historic road between Venice and Augsburg, the great artery of commerce in those days between Germany and the mistress of the Adriatic. As showing the extensive nature of this trade at the present day it is interesting to note that the quantity of vinegar required during the three months, which constitute the main fishing season, averages 350,000 litres, all made from grapes. Marinated smelts, called in the Italian trade *Aquadella fritura marinata*, are treated somewhat differently from eels, partly because of their smaller size and more delicate nature and partly because of a deficiency of oil in their tissues. Instead, therefore, of being spitted and roasted, they are first rolled in flour and then fried or rather boiled in oil. The oil used is that collected from the eels during roasting; in this they are boiled for five minutes in copper caldrons, the flour in which they were rolled imparting an appetising appearance and colour to the finished product. After frying they are laid out to cool and to drain thoroughly. As with eels, after they are cool, they are packed in barrels, which are filled with vinegar after being headed up, and then left to stand awhile before the bung is inserted.

A small quantity of the marinated fish is packed in tins of various sizes, but this method does not appear to be greatly developed as yet. As already mentioned approximately two-thirds of the eels caught are marinated. The remainder is sold alive, special live cars, often of large dimensions being employed to convey them often to distant cities along the coast and up the River Po. They have the form and appearance of a flat-bottomed lake boat ; they are sharp at either end and are fully decked over. The sides and bottom are perforated with rows of long narrow slits thus— . They have no internal partitions and have but a single square hatchway closed with a sliding cover capable of being locked and well secured. The live cars, when prepared to convey quantities of live eels, are corded round with many lashings of rope to enable them to stand the strain of towage.

Similarly shaped craft (*marota*) but of greater size are employed in large numbers as storage receptacles whenever very large catches of fish are made in the labyrinths. If the marinating factory is to be run economically, it is obviously essential that a steady supply of fish shall be available during the working season, hence the value of these great store chests. A usual size is 15 metres long by 3 metres beam ($49 \times 9\frac{3}{4}$ feet), with a depth of 2 feet ; each fishing station has a number stored away in its store-sheds ready for use and as the eels live for days and even weeks in them without harm, the administration is prepared to take full advantage of those notable nights when great multitudes of eels simultaneously develop an instinct which urges them to seek a way to the sea. In a single night as much as 20,000 quintals (about 200 tons) weight of fish may be taken from the pounds ; the factory requires some weeks to dispose of such a quantity, so were it not for the employment of many *marote*, work would be forced at a wasteful pace and much of the fish would otherwise be lost.

Besides these wooden boat-shaped store receptacles, numbers of spheroidal wicker pots of large dimensions, 6 feet to $7\frac{1}{2}$ feet diameter, are used for the same purpose. When comparatively small quantities of fish have to be stored, these wicker pots are

preferred to the larger and more cumbersome wooden live-chests.

Eels and mullet are also occasionally prepared for market by smoking and whenever phenomenally heavy catches are made, as for example during an exceptionally dry season when the excessive salinity of the lagoon drives all species and all ages of fish to attempt to escape therefrom, then resort is had to the salting and sundrying of such fish as are not suitable for marinating and of those quantities which are beyond the capacity of the storage receptacles. The preparation of salt fish under these circumstances is an exceptional expedient resorted to only to save the fish from being utterly lost. Except under stress of necessity this method of preparation is not practised as such fish brings in poorer prices than does either live or marinated fish. The last-named is the favourite as it is the only method of curing known at Comacchio which gives better returns than the sale of live fish, 110 lire being a fair average price for 100 kilos of marinated eels as against 80 lire for the same weight in the fresh (living) state. Mullet are worth fresh about 60 lire per 100 kilos, smelts 30 lire, and gobies about 21 lire.

Administration.

Since this great fishery establishment became the property of the Commune of Comacchio, it has been administered for the general good by a communal or municipal committee who arrange all matters relating to the upkeep, policing and fishing of the various sections of the lagoon.

The communal administration may also undertake the preparation for market of the produce of the fishery, but under ordinary circumstances the total produce for a term of years is offered for public tender at periodical intervals and it is only when no satisfactory contract is possible that the commune organizes a manufacturing department charged with the curing and wholesale distribution of its products. Such an eventuality arises only after or during one of the periodically recurring crises which afflict the industry when a succession of abnormally dry seasons entails wide-spread death and loss of fish; the length of these cycles of poor seasons being indefinite,

commercial firms naturally hesitate to take the heavy risks involved by a tender based on normal returns and so discount the risk by heavy reductions in the sums they offer for the produce of the lagoon. Cycles of unremunerative years usually fall to be worked by the commune, whereas during cycles of prosperity, competition for the fish-contract is usually satisfactory.

Each large valle or group of smaller ones has its separate staff of workmen and fishers presided over by an experienced chief, the *fattore*. These men are accommodated with quarters in the fishery building found at each of the principal fishing stations. Here they live and mess together like soldiers in barracks, a necessity consequent upon the fact that the chief work of the year, the herding of the fish into the labyrinths, takes place during the night. The life is hard and trying but custom and the traditions of centuries of such conditions render the men passively content, satisfied if they be allowed a couple of days, Saturday and Sunday, on alternate weeks to revisit their families in Comacchio. To permit of this arrangement half their number take holiday in alternate weeks.

The working staff struck me as a fine body of men; true handy men they are, for their duties include the supervision of the entry of the fry from the sea during the spring, the repair of the dykes, the weaving of the reed screens, the construction of the labyrinths and sluices and the collection of the fish. A ration of fish is given them in addition to wages. Repairs to the embankments and fishing stations are executed during the hot season (June, July and August) when the water in the lagoon is low and other duties are light.

The work of policing is done by a separate staff of over one hundred men who patrol the lagoon in light boats both day and night. Their duties are no sinecure for there are many poachers in the villages around the lagoon and even in Comacchio itself. Coste stated his belief that fully as large a quantity of fish is stolen by these poachers, as is fished by the administration. Seeing that the perimeter of the lagoon is 177 miles, the opportunities for theft are undoubtedly very great, but while admitting this, I cannot believe that such an enormous loss of fish is possible; I incline to think that

Coste in his desire to exhibit the Comacchio establishment as a model of everything excellent in marine fish-farming, took this means to explain away, in part, the extremely poor yield of fish per acre of water surface as exhibited by the official statistics.

The central administration has the technical advice of a trained engineer who supervises the general mechanical arrangements, particularly the management of the sluices and the reclamation of land from the lagoon. Of late years it has become evident that permanent deterioration of the fishery can only be prevented by the assistance of science, and so the engineer to the administration is now required to have biological knowledge as well as an engineering training. The late Engineer, Signor Samaritani, appreciated the absolute necessity for a thorough biological knowledge of the lagoon and its inhabitants and laboured long but without success to gain the assistance of Government for the establishment of a biological station in the lagoon.

In cases of sudden crisis, the administration follows the excellent custom of calling to its council not only its engineer but also the working superintendents (*fattori*) of the different valli, and any old servants whose length of experience entitles them to consideration.

Revenue.

The annual net profit derived from the fishery has been and still is subject to enormous fluctuations owing to the alleged impossibility of warding off the evil effects of series of abnormally hot dry seasons which occur irregularly from time to time. Fortunately the cycles of prosperity have usually been much more prolonged than those which are not remunerative, and there is every reason to believe that the years of unremunerative fishing will be largely curtailed now that the empirical methods of the past are being submitted to the touchstone of science, which by experiment and deduction has already effected a measure of amelioration. When Pope Clement VIII in 1598 seized the lands pertaining to the ducal house of Este, Comacchio was included, and this family claimed that they derived annual revenue from the fishery of 500,000 lire. These figures are possibly exaggerated as in 1587, it appears that the Estes had farmed it out

for 333,000 lire.* Be that as it may, after Rome seized the fishery, its value began to decline; from 1725 to 1748 the average net revenue was only lire 74,480. Thenceforward it gradually recovered, being lire 104,931 for the years 1749 to 1757, while from 1767 to 1797 it rose to an average of lire 322,640.† At the end of the last-named period, the fishing rights in the lagoon were sold by Napoleon I to the Commune of Comacchio. The ensuing period of 16 years, if we can trust Pepoli's figures, mark the high tide mark of prosperity in the history of the lagoon, for the average net revenue from 1798 to 1813 inclusive is given as lire 567,749 per annum. The figures for the next period, 1814—1825, show a large falling off, the annual net revenue varying between lire 200,000 and 250,000. 1825 marks the year of greatest disaster in the history of the establishment; almost the whole stock of fish throughout the whole lagoon perished through the partial drying up and consequent extreme salinity of the water. The Government thereupon was forced to resume the fishery and held it till the end of 1868 when it was handed back to the administration of the local Commune. During this period the Government paid a sum varying between lire 89,000 and lire 75,000 per annum to the Commune as compensation for occupation of the fishery, but the bargain was a bad one for the Government as five separate disasters, in 1825, 1834, 1850, 1859 and 1865, entailed an average annual loss of 246,408 lire.‡ Strangely enough, the return of the fishery to the direct governance of the Commune marked once more the beginning of a long period of prosperity, for, during the 22 years from the end of 1868, the net annual revenue derived from the leasing out of the produce varied between lire 121,318 and lire 185,000. The hot summers of 1890–91 entailed great loss and for a number of years the Commune being unable to lease the fishery, had to conduct it at great loss. With the close of last century recovery was made and it was again possible to lease the catch of fish at a remunerative rate. The fishery is now bringing in a net annual profit ranging between lire 120,000 and lire 180,000. The mean of these

* SAMARITANI, Prov. necessari nella laguna di Comacchio, p. 14.
† BULLO, *loc. cit.*, p. 369.
‡ SAMARITANI, *loc. cit.*, p. 6.

figures or lire 150,000 (Rs. 90,000) is a fair approximation of the net average annual profit derived by the Commune during any series of years marked by normal conditions. Such a series is now current and a similar cycle lasted from 1869 to 1891 as noted above when the income varied between the same limits.

Samaritani arrives at identical results in a calculation of the net annual profits upon the working of a period of 15 years ending with 1883. For this series he states the average yield of fish as :—

843,564 kilos of eels.	74,124 kilos of mullet.

He calculates that two-thirds of the eels will be distributed in the marinated condition at an average price of lire 110 per quintal (Rs. 66 per 220 lb., say 4 annas 10 pies per lb.), and that the remainder of the fish will be sold fresh, the eels at lire 80 per 100 kilos (Rs. 48 per 220 lb.) and the mullet at lire 60 per 100 kilos (Rs. 36 per 200 lb. or 2 annas 8 pies per lb.).

On this basis he estimates the proceeds as follows :—

	LIRE.
Two-thirds of the eels, sold marinated at lire 110 per quintal	618,613·60
One-third sold fresh at lire 80 per quintal ...	224,950·40
74,124 kilos of mullet at lire 60 per quintal ...	44,474·40
Sale of smelts and miscellaneous fish ...	6,000·00
Sale of hay and rent of pasturage	11,800·00
Shooting rents	3,600·00
Sundry receipts	5,000·00
Average gross annual receipts ...	914,438·40

The annual expenditure does not vary in correspondence with the fluctuations in receipts, and may be taken to average 750,000 lire, the precise mean of 26 years being given by Samaritani as lire 755,230. Deducting this sum from that given above as the average gross receipts, we find the net annual profit of the undertaking to be lire 159,208. The area of the lagoon during these years was 39,500 hectares, so this sum is equivalent to a working profit of lire 4·05 per hectare or lire 1·66 (exactly one rupee) per acre, an extremely unsatisfactory

return compared with that at Arcachon which as stated on page 17 amounts to as much as Rs. 60 per acre.

The significance of these figures led Samaritani in 1884 to advocate the relinquishment of fish farming in favour of reclamation of the whole lagoon. He was then Engineer to the Communal Council of Comacchio with intimate knowledge of local agricultural and physical conditions. In a report to the Council in the year named he discussed in detail the advantages of such a policy. The gist of his conclusions was that if his proposals were carried into effect, instead of a present annual profit of about lire 150,000 made from fish farming, the commune may expect to obtain an annual revenue of from lire 2,370,000 to lire 4,345,000 if the lagoon were reclaimed for the cultivation of rice, beetroot, hemp and grapes, the crops which yield best in this region. His figures were as follows :—

	LIRE.
1. Annual income calculated from the returns actually obtained from sections of the lagoon already reclaimed	4,345,003
2. The same calculated on the mean return from all kinds of reclaimed land in the province of Ferrara	3,367,375
3. Revenue based on the returns from lands occasionally flooded by the sea	2,370,000

These returns are equivalent to an annual revenue of lire 110, 85¼, and 60 respectively per hectare, as compared with lire 4 per hectare yielded by the lagoon as a fish-farming establishment. Samaritani concluded by stating that while the first rate is that which he believed to be reasonable from a study of existing facts, the second should be acceptable by the dubious and the third should convince even those who are incredulous of the great benefit to be derived from reclamation.

I ought to mention in this connection that the conditions for profitable reclamation are exceptionally favourable at Comacchio. The general level of the bottom of the lagoon lies from 1½ to 2 feet above low tide level and several series of embankments parallel with the coast already exist. If the two seaward openings be closed and the existing sea-canals converted into main drainage channels, the expense of reclamation would be comparatively small.

So far the commune has preferred to pursue a middle course—to improve the conditions in the better class of their fish farms and concurrently to undertake the reclamation of the sections less favourable for fish rearing, so that over 3,000 hectares of what was water surface at the time of Coste's visit have now passed permanently into agricultural occupation. The process is likely to be continued until the whole inner half of the lagoon, lying from 10 to 20 kilometres distant from the sea, shall come under tillage, leaving the seaward half to continue as fish farms.

Conclusions.

Comacchio furnishes to the fish culturist many object lessons particularly valuable in India where the efficient utilization of extensive tidal backwaters analogous to that of Comacchio is one of the principal problems now before the Madras Fishery Department. These demonstrations fall into two divisions, those that are lessons in methods that are admirable and those that are instances of faulty and defective procedure to be carefully avoided or materially modified and improved.

In this connection it is necessary to emphasize the fact that the lagoon of Comacchio is in reality not an establishment of fish culture properly so-called; it is merely a complex system of lagoon fishing whereby the fish which enter as fry have their escape barred, to be captured *en masse* as successive broods reach maturity, a system handed down without appreciable alteration through fifteen centuries. In the middle ages it appears to have given much greater returns than the average for the past two hundred years, and present methods call for material modification if the yield of fish per acre is to be increased to adequate proportions. At present the yield does not average more than 50 lb. per hectare or about 20 lb. per acre, a wholly inadequate rate considering the known potentialities of water areas cultivated on scientific principles. Empirical as are the methods of the Arcachon fish farmers, they actually produce per acre twelve times the weight of fish yielded by Comacchio for a similar area, the average of two years' yield in France being 608½ lb. per hectare annually.

To formulate in detail any scheme for the improvement of the Comacchio industry does not enter into the scope of this report; for present purposes it will suffice if I enumerate what in my eyes appear to be the principal defects of the existing system and note the general principles upon which any permanent improvements must be based.

In the first place the present area is too extensive to receive adequate cultural attention. Worse still, the major portion is so remote from the sea that it is impossible to provide means for tidal freshening, a measure essential to the permanent well-being of a lagoon such as that of Comacchio. Experiment has shown that in the canals connecting the valli with the sea, no tidal rise and fall is marked at a distance of 10 kilometres from the sea mouth. The two great valli, Mezzano and Fossidaporto, constituting almost one-half of the lagoon, are both beyond this distance from the sea and hence cannot possibly be benefited appreciably by ordinary tidal flow. The frequent freshening rightly considered to be vitally important in the case of French fish farms is virtually absent here. This lack of control over these great expanses of water is the basal reason for the disasters which punctuate the history of the lagoon, and till it be removed the prosperity of the establishment is at the mercy of the seasons. All other defects are of very minor importance compared with this.

Were the fish farm area of the lagoon reduced by means of the reclamation of the sections remote from the sea, and effort concentrated upon a number of small valli contiguous to the sea-bar, it would, I am positive, be at once possible to render stable the commercial success of the industry by eliminating or at least reducing to unimportance the dangers and losses hitherto attendant upon the occurrence of abnormally dry seasons. It would then be possible to devise means for the admittance of tidal water at frequent intervals and in large volume, the salinity of the enclosed waters would never appreciably exceed that of the sea, large supplies of plankton would be available as food, and in presence of the healthier conditions set up by the alternate ebb and flow of large volumes of water, the growth of the fish would be accelerated. The great losses now

experienced on account of wholesale poaching would be materially lessened, the reduced area permitting of more effective supervision. There can be little doubt that under these improved conditions the yield of fish would be largely increased; the present yield per acre is so small that a very slight improvement in methods should enable double the present catch to be made—40 lb. per acre is all the quantity required in order to make such improved seaward half of the lagoon yield as much revenue, at less expense, than does the whole area in its present condition. In addition, the Commune would then be receiving rental upon 45,000 acres of agricultural land obtained by reclamation of Valli Mezzano and Fossidaporto. Under wise and energetic guidance the Commune should be able to develop its lagoon into a property yielding not £6,000 a year but £50,000 at the very least—reclamation of half the present area should bring in not less than £45,000 (the rental calculated at £1 per acre) while if fish culture and not mere fishing be practised in the remaining area, the yield therefrom in fish should be quadrupled without difficulty in which case net profit of £10,000 to £12,000 should accrue from this industry.

When I say fish culture instead of fishing, I mean that instead of herding all species together as at present, separation to some extent should take place, and that special attention be given to the introduction and culture of other species beyond those now reared. The fry of some of these would probably have to be supplied from hatcheries, but in these days when plaice, and cod and shad are hatched by the million under artificial conditions, this would present no difficulty. The provision of artificial food to supplement natural resources in selected ponds of limited area is another innovation likely to prove economically sound; it would enable the yield to be enormously increased of those ponds where it might be possible of introduction. But these are details that must be decided and worked out by an expert on the spot.

In spite of all imperfections, the present system has served Comacchio well; it has been the mainstay of the population for 1,500 years and the reluctance exhibited to risk the consequences of any radical change need not be

a matter for surprise. Directly and indirectly the fishery furnishes the means of regular subsistance to some 2,500 people and furnishes a surplus for the general purposes of the city which seldom falls below £6,000 per annum. Comacchio is a remote and isolated community and such is ever intensely conservative and loth to embark upon new enterprises so long as day to day needs are met under the system handed down from preceding generations.

III.—THE SCOPE FOR MARINE FISH-FARMING IN INDIA.

In the foregoing pages have been described the fish-farming methods practised in France and in Italy, the only countries where this industry is carried on upon a large scale. We have now to consider to what extent and with what modifications the principles underlying these systems may be adapted to Indian conditions in order to increase the food-supplies derivable from back-waters, estuarine creeks, and sea-ponds along the coast.

This enquiry requires consideration under three heads, namely :—

(*a*) The species of suitable fish available in the Madras Presidency.

(*b*) The waters available and suitable; their characters and extent.

(*c*) The procedure considered most likely to prove successful as being adapted to local conditions.

The Species of Fishes suitable for the purposes of Marine Fish-farming in Madras.

At Arcachon, the marine fish found to thrive best and give satisfactory results in captivity are eels, mullet of several species, and the bass (*Labrax lupus*). The fry of soles and plaice also enter the ponds in large numbers but as no means are taken to confine them in separate enclosures all but a small number fall victims to the rapacity of old eels while yet quite small owing to their sluggish habits and life preference for the bottom. Mullet and bass, although they too pay a heavy toll to the eels, survive to maturity in considerable numbers as they are much more active and restless in their movements than flat fish and when young pass most of their time swimming near the surface in shallow parts of the ponds little frequented by the mud-loving eel. The mullet like the eel is tolerant of even considerable changes in the salinity of water; it feeds largely upon minute plant life which is usually more abundant in brackish water than

in the open sea, and for these reasons and because it and the active and omnivorous bass and the voracious eel have different feeding habits, these fishes form an admirable trio for the purpose of the fish farmer in France.

At Comacchio eels and mullet are found to live well together ; these two species form the bulk of the produce of the lagoon. Sand smelts (*Atherina boyeri*) and Gobies (*G. lota*), furnish considerable quantities in some years, the former giving from 70,000 to 90,000 kilos per year, the latter from 2,000 to 3,000 kilos. These two fishes apart from the direct contribution they make to the revenue of the fishery are of immense importance as food for the eels—the immense shoals of aquadelles, as *Atherina* is termed at Comacchio, constituting their chief nourishment during the greater part of the year. The other species of fish which thrive in these fish farms comprise bass, soles, plaice and sea-bream (*Sparus aurata*) but although they constitute a notable proportion of the fry which enter from the sea comparatively few survive to maturity.

Shrimps (*Crangon vulgaris*) and *Carcinus maenas*, the common shore crab of Europe, enter in enormous quantities when the sluices are open for the *montata* in the spring and as they also breed freely in the lagoon, they furnish an indispensable and never failing source of fish-food.

The ability not only to withstand and survive comparatively considerable variations in the salinity of the waters they inhabit, but to thrive almost equally well whether the salinity be high or low—within reasonable limits—is the most important attribute to be considered when deciding what species are best fitted for culture in marine fish farms. The ponds employed cannot be put in fully free communication with the sea, and hence in dry seasons may tend by reason of rapid evaporation to become comparatively highly saline, while on the other hand the occasional torrential rains and high floods which are factors in the situation in India wheresoever the pond might be situated, are bound to reduce the salinity below the normal at certain seasons.

Unfortunately there is lack of precise information available on this point. Among European fishes suitable

for pond culture * it is a matter of common knowledge that eels and certain species of mullet have been found by experience to possess the widest range of tolerance, the bass not far behind, and Bullo has compiled a table giving the maximum and minimum range of tolerance of salinity for these and other lagoon fish. The figures given are admittedly tentative, the author stating that the table is founded on deductions from rough data provided by the empirical working of Italian fish-farms ; it cannot be accepted except as an approximate guide. It is probably unreliable in details, but since it is almost the only tabulation of the kind we possess, it will be of use to reproduce it here. The figures are as follows :—

TABLE showing the limits of salinity tolerated by the principal animals reared in Italian lagoons, after Bullo.†

Name.	Limits of tolerance.	
	Minimum (parts per 1,000).	Maximum (parts per 1,000).
Fishes.		
Goby (*Gobius lota*)	24	40
Golden mullet (*Mugil auratus*)	24	35
Smelt (*Atherina Boyeri*)	20	40
Sea-bream (*Sparus aurata*)	21	40
Sole (*Solea vulgaris*)	25	40
Plaice (*Platessa passer*)	20	40
Leaping mullet (*Mugil saliens*)	16	40
Thick lipped mullet (*Mugil chelo*)	10	40
Bass (*Labrax lupus*)	10	40
Grey mullet (*Mugil capito*)	5	40
Large headed mullet (*M. cephalus*)	4	40
Eel (*Anguilla vulgaris*)	0	40
Crustaceans.		
Common shore crab (*Carcinus maenas*) ...	26	40
Common shrimp (*Crangon vulgaris*) ...	26	40
Molluscs.		
Common cockle (*C. edule*)	16	40
Edible mussel (*M. edulis*)	25	40
Oyster (*Ostrea edulis*)	18	35

* Anadromous fish such as the salmon and the sturgeon are excluded for obvious reasons.

† *Loc. cit.* p. 176.

Considering that the salinity of the open sea in Europe is about 35 per 1,000, this table credits none of these fish with a tolerance of exceptional salinity. Its chief inaccuracy appears to be in regard to this statement; later writers, particularly Samaritani and Feletti, adduce facts which show that the eel in particular can endure a much greater salinity than 40 per 1,000. The former writer states that to his knowledge eels are able to adapt themselves to a salinity of 8° Beaumé (= 80 grams of total salts to 1,000 grams water); further that in June, July and August 1893 the salinity of the Comacchio valli, and in particular the Mezzano, rose everywhere to 7° and 8° Beaumé and in a certain locality even to 10°, without, in that year, causing any mortality. He notes specifically that the fish were *sana e vivacissima*. How far a high salinity, say between 40 and 60 per 1,000, is inimical to the *growth* of eels is unknown; experiments upon effects produced by variation in salinity upon fishes in captivity are urgently needed—we require to know the limit of tolerance wherein each species can exist, and, more vitally important even than this, we must obtain precise data as to the optimum of salinity, in order that we may eventually regulate this to the degree best suited to the rapid growth of the fishes under control.

Eels, several species of mullet, smelts, bass, sea-bream (*Sparus aurata*), gobies, plaice, and soles being the chief food fishes which are found to thrive in captivity in Europe, it is satisfactory to know that fishes of closely related species and of similar habits are found in Indian waters in fully as great numerical abundance as in Europe. Eels are represented by two species, mullet by not less than 27 species, several being noted for their marked partiality for backwaters, and some being actually domiciled their whole life in rivers, smelts by three species of *Atherina*; in place of the bass we have the finer *Kodawa* (*Lates calcarifer*); sea-bream are represented by several species of *Chrysophrys* which resort habitually to backwaters at certain seasons; gobies by numerous species of the same genus; plaice by the fine *Pseudorhombus arsius*, and soles by several species of estuarine-loving *Cynoglossus*. The fry of certain species of all these genera of Indian fishes resort to backwaters

and estuaries in vast multitudes at certain seasons, and from the fact that their European representatives thrive in captivity, these kinds are marked out as specially well adapted for cultural purposes. But this list does not exhaust by any means the number of kinds which appear suitable for culture ; it omits several of the very best, species probably of greater value than the majority of those already named. Principal among these additional species are the various kinds of bámín or kála (*Polynemidae*), and the so-called "whiting" of Madras (*Sillago* spp.) ; the fry of all these frequent estuaries and, according to Day, so also do the young of that most excellent of fish, the white pomfret (*Stromateus sinensis*).

At the present time we know almost nothing definite about the habits of Indian sea-fishes ; the acquirement of precise information on this subject in regard to the more esteemed of our food fishes is pressing, and the selection of fishes for the initial culture experiments must be tentative. We have yet to find what fishes will thrive best under the peculiar conditions attendant upon confinement ; we may easily make a wrong choice ; we have also to find what species may be reared in the same ponds, and we have to learn whether we can depend upon the natural *montata* or "mounting" of the fry to supply the ponds or whether it will be preferable to hatch fry artificially.

Two distinct considerations enter into the problem of the selection of species for cultural experiment—the first is hardiness to bear occasional variations in salinity, to endure prolonged confinement, and a diet more restricted perhaps than that normal to the species, the other is the quality of the fish from a table point of view. We have already seen that eels and mullet belong to the first category, but we are ignorant of how far the bámín, the "whiting" and the white pomfret conform to this requirement, and it happens that these latter fishes together with the mullet, are the kinds most esteemed of the whole number available, whereas eels and catfish, hardiest probably of all, are those of least commercial value in India, whatever the former may be for purposes of export.

A few notes detailing the salient facts of cultural import concerning the species enumerated may usefully

be given here, but they are at the best meagre and their amplification should be one of the first and most important tasks to which the attention of Indian fishery officers should be directed. Efficient work is impossible without satisfactory and sufficient data and these we do not possess.

EELS.—Of these two species are recorded by Day* *Anguilla bicolor* and *A. bengalensis.* These fish, the *velángu* and *pámbu mín* of Tamil districts, abound in muddy creeks and estuaries on both the East and West coasts. They are not often caught by fishermen and then only by accident, as no native will fish for them purposely owing to the very general objection of natives of India to eat them owing to their snake-like form and supposed absence of scales—the latter being specially objectionable in the eyes of Muhammadans. The size attained by eels in India appears fully as great as in Europe and there can be little or no doubt that their life-cycle and habits coincide with those of related species in other parts of the world.

The remarkable migration of young eels or elvers from the sea into rivers and fresh-water lakes, their sojourn there for 4, 5 and even 6 years, and their eventual return to the sea to breed, are phenomena known for centuries and utilized commercially as we have seen by Italian fish farmers for at least 2,000 years. Where and under what conditions the sexually mature eels congregate and breed and what the larvæ are like remained an enigma until a few years ago. The researches of Grassi and Calandruccio first solved the latter problem; they were able to demonstrate by direct experiment and otherwise that certain forms of pelagic ribbon-shaped fish-like creatures, previously known as Leptocephalids and considered to belong to a special and separate family, were in reality the larvæ of the common European eel. The species of Leptocephalus so identified is the one named *L. brevirostris,* Kaup. Eingenmann and Kennedy subsequently established the identity of another from, *L. Grassii,* Eing. & Kenn., as the larva of the American eel, *Anguilla chrysypa.* Leptocephalids have been found by both Day and Thurston in Indian seas; the latter

* Fauna of British India—Fishes, London, 1889.

observer in Bulletin No. 3 of the Madras Government Museum (1895), mentions that he "obtained a few specimens in the Gulf of Manaar and a large number from the meshes of fishermen's nets at Gopalpur, where they are known as sea-leeches." * At that date their identity with the eel-family was unknown and Dr. Thurston quoted Gunther's strange theory that they represented the larvæ of various marine fishes living a pelagic life in an arrested and abnormal stage of development!

The identity of these larval fishes once established, the completion of our knowledge of the life-history of the eel became a question of the greatest interest to marine zoologists and to-day many of the blanks have been filled up. The range of Leptocephalid larvæ was extended into the Atlantic by the capture by Schmidt and also by Holt in 1904 of single specimens in the Atlantic. The following year Schmidt obtained numerous individuals by means of the Petersen net, and was thus enabled to determine some of the oceanographic conditions under which they occur. The chief facts ascertained during these memorable investigations are that the leptocephalids of North European eels are not hatched in shallow seas and that they are most numerous along the course of the narrow band lying between the 500- and the 600-fathom line of the Eastern Atlantic. They were taken at various depths down to 1,000 metres, a depth where the temperature is above 42° Fahr. and salinity above 35 per 1,000. The greatest hauls were made in the neighbourhood of a depth of about 70 fathoms. Other facts lead to the belief that the breeding of the eel occurs at great depths. Large specimens of the adult form of the eel have been obtained by Grassi and Calandruccio from the whirlpools in the Straits of Messina which occasionally bring to the surface animals known to live at abyssal depths; these eels, while having the dark livery of the breeding season, were more deeply pigmented and were marked by an extraordinary increase in the size of the eyes. Vaillant also records the extraction of an eel, 90 centimetres long, from the stomach of a Cachalot whale captured off the Azores.

* The latter probably were not true Leptocephali; it is more likely they were elvers. J. H.

These and other observations, taken together with the above-mentioned facts regarding the distribution of leptocephalids lead us to conclude that the breeding place of eels is in depths somewhat greater than 500 fathoms in conditions where the temperature is above 42° Fahr. and the salinity above 35 per 1,000.

This brief resumē of the state of our knowledge concerning the early history of the eel shows the impossibility of utilizing methods of artificial propagation in the case of this eel. To stock fish-ponds with eel-fry, dependence must be placed upon the migration shorewards of the shoals of elvers, the colourless fry into which the leptocephalid larvæ change when a certain age has been attained. These elvers when they first arrive on the coast average 7 centimetres in length, actually smaller than the leptocephalid larvæ from which they come!

Eels in the sedentary stage are carnivorous and extremely voracious. They are most inimical to young fish of all species, but particularly to such as live near or upon the bottom. Wherever fish of greater value than eels are to be reared, it is necessary to keep them in separate ponds. At Comacchio, smelts and crabs form the chief food of captive eels, a diet which should be duplicated without difficulty in Indian fish farms.

Because of its rapid growth due largely to its indiscriminate voracity and its ability to withstand great variations of salinity, the eel is the most easily reared of any species available for fish-farming in saline waters. Precise data upon the rate of growth under definite conditions are not available even in Europe, and, if they were, it is probable that they would not be reliable guides to that attained in Indian waters, where conditions are usually more favourable. It may be mentioned however that Coste, who was almost the first to give scientific attention to the growth of fishes, stated that an eel fry attains a weight of 2½ kilograms "within 4 or 5 years," while Gobin is responsible for the statement that "a kilo of *montee* of eel fry containing 3,600 individuals, attain in three years a weight of 6,000 kilos and a value of 3,000 to 3,500 francs (Rs. 1,800 to Rs. 2,100).*

* La Pisciculture en eaux salees, p. 212, Paris, 1891.

In Germany the rearing of eels in fresh-water ponds is a wide-spread minor and accessory industry, and is undoubtedly exceedingly profitable, the owners usually marinating their products for local consumption.

In Northern Europe Gemzoe * has found from a study of the concentric zones marked on the scales that the age at which development of the breeding instinct leads female eels to begin a migration to the sea ranges from $6\frac{1}{2}$ to $8\frac{1}{2}$ years, whereas in the male the migratory instinct appears to be developed between 4 and $7\frac{1}{2}$ years of age. It should be noted however that three years must be added to the number indicated by the zonal markings, as scales do not appear till two years of sedentary life have elapsed, while if the deductions of Schmidt be correct a third year must be added to cover the pelagic or larval period. Hence the actual age of an eel is three years greater than that of or indicated by the scale. (In deducing age from examination of scale markings, it is necessary to select those close to the lateral line; these are earliest to appear.)

The eel is a fish universally esteemed in Europe; in England although it is less popular than on the Continent yet the local supply falls so far short of the demand that London receives annually large consignments from Holland.

Marinated eels as prepared at Comacchio and throughout Germany form one of the most nutritious and appetizing of preserved foods. Owing to prejudice it would have a restricted consumption in India at the commencement, but it has only to be once tasted to be appreciated and, as a food and a luxury for the well-to-do, it should attain popularity in spite of prejudice. However if a large and regular supply can be depended on, local demand is not essential to success. If barrelled and tinned as at Comacchio, an export trade to Australia and Central Europe should be profitable as there the demand is normally in excess of the supply—a demand that increases annually in pace with the fecundity of the German race, whereas the supply lacks elasticity and corresponding increase.

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* Age and Rate of Growth of the eel; Report of the Danish Biological Station to the Board of Agriculture, XIV, 1906, Copenhagen, 1908.

Mullet.—Mullet in European fish-culture rank next after eels ; India is specially rich in species of this family of fish ; they constitute the most abundant fish found in estuaries and backwaters. In India the range of habitat is greater even than in Europe. Some species remain permanently in rivers, other keep rather strictly to the sea, while the remainder, which specially concern us, enter backwaters and estuaries in immense numbers both as fry and as adults. The most ingenious of the nets used in backwaters, as at Ennore and Pulicat, are designed to capture these wiliest of fish.

In confinement they exhibit in a large degree the quality of hardiness ; they are easy to feed and will live where most other fishes would die from starvation. They feed largely upon vegetable growth and debris ; at the same time they will feed voraciously upon shoals of small crustaceans when opportunity offers. The general opinion is that mullet with the exception of the species domiciled permanently in fresh waters, spawn in the sea. This I have reason to believe is not the case universally * as I have seen fully grown female mullet ranging from 18 to 21 inches long taken from Ennore backwater in numbers in the middle of January with fully developed ripe roes. They were always accompanied by a larger number of males also in ripe condition. As the females were of quite different dimensions to those living in the backwater a month earlier, there is no doubt these fish had entered the backwater from the sea not long previously. A significant fact was that the stomachs of the females were empty ; the stomachs of the males were crammed with a tangled mass of green algæ. The former had apparently not entered the backwater to feed ; the inference is strong ; they had entered with intent to spawn. However this may be, it is a matter urgently demanding settlement ; there would be no difficulty in collecting an ample supply of ripe breeders in January at Ennore and Pulicat if it were desired to strip them when ripe and practise artificial fertilization and hatching, procedure which is altogether preferable to depending upon supplies of natural fry whenever a skilled staff is available ; the former system allows full

* In Europe instances are on record of mullet thriving and breeding freely in ponds fed principally by fresh water during the greater portion of the year.

control of the species treated and obviates the mixing of different species of fishes in the ponds.

Mullet are industrious feeders ; apart from the question of the possible direct absorption of carbon compounds dissolved in sea water, they grow fat on a diet of mud when this is laden with diatoms or other minute algæ—possibly even when such are absent and the organic matter present has resulted from decomposition changes. Thus these fishes pick up food where other species would starve. They increase rapidly in size ; according to Coste, mullet living in Comacchio lagoon increase from 3 centimetres in length to 26½ centimetres (10½ inches) during a period of 12 months. The table of growth which he gives may usefully be reproduced here, in order that a comparison with the rate of increase in Indian waters may be instituted when this information be obtained. Coste's figures are as follows :—

Age in months ...	1	2	3	5	6	7	9	10	12
Total length in centimetres.	3	5	8·5	13·8	16·5	19	21	24	26·5
Greatest girth in centimetres.	1·3	2·0	4·2	7·0	8·0	9·5	11·0	12·0	13·5

From my knowledge of the life conditions in Indian backwaters, I feel assured that these figures are considerably exceeded here ; indeed I expect to find that mullet attain a good marketable size at the end of one year from the time they enter the ponds as fry.

Polynemids, the *kāla* of Tamil fishermen, and the bamin of anglers, constitute another family of food fishes in high esteem in India. Off Point Calimere and in Palk Strait they are the subject of an important special fishery and along both the East and West Coast they are eagerly sought both by professional fishermen and by the votaries of Isaak Walton. Either fresh or salt cured, bamin is one of the very best flavoured fish for the table, and Sir Frederick Nicholson has found it to give an extremely satisfactory product when smoked. So highly esteemed is it that it is called sometimes the Indian salmon.

P. tetradactylus is probably the most valuable species on the Madras Coast. It is the largest among Indian species, attaining 6 feet and upwards in length

when fully grown ; it is tolerant of changes in salinity and exhibits great partiality for backwaters and estuaries. For these reasons it is indicated as a species well adapted for rearing in confinement. The larger polynemids are essentially predatory fishes. They are the special and particular enemies of mullet, following them into backwaters and penetrating far up tidal rivers in the pursuit. Some species enter rivers and backwaters for spawning purposes ; as with the mullets, there should be no difficulty in obtaining fertilised ova for artificial hatching.

Provided sufficient supplies of suitable food be present or procurable, polynemids should be found to be among the three most profitable kinds of fish available in India for fish-farming. They grow rapidly, attain a large size, are tolerant of the variability characterizing backwater life-conditions, and are obtainable as fry in the requisite abundance ; finally, when put upon the market they will always command a ready sale at prime fish prices whether fresh or smoked.

The White pomfret (*Stromateus sinensis*) is another of the highly valued Indian food fishes which it may be found possible to utilize for pond culture. The young are said to frequent estuaries and it is probable that they would bear confinement well. They feed largely upon small crustaceans, worms and the like, and their food supply should not present any serious difficulties. At present their breeding habits are little known and we cannot go further than express the opinion that the probabilities are that their eggs should be readily obtainable for artificial hatching purposes and that the fry are likely to thrive well in backwater ponds. Experiments must be undertaken to ascertain the most suitable conditions under which successful culture on a large scale may become possible.

Were the present Madras Aquarium capable of accommodating a small fish-hatchery consisting either of batteries of Macdonald jars or Dannevig oscillating boxes, the necessary facilities for this and other investigations would be available at a very low cost ; unfortunately when the building was designed no provision for this purpose was included and it will now be necessary to build a separate hatchery with observation tanks, etc., for the conduct of fishery experiments.

Mullet and pomfret should go well together in the same ponds; in feeding habits they appear to be complemental, the one fond of plant growth, the other of the small animal life easily propagated in ponds. Neither would interfere inimically with the other. What are the prospects of acclimatising in ponds the fry of the other two species of pomfret (the grey and the black) cannot be stated, so little is known of their habits. In favour of the possibility of so treating them is to be counted their somewhat phlegmatic habits. They are comparatively slow in their movements and fish of this temperament usually adapt themselves readily to the irksomeness of confinement.

The SEA-BREAMS (*Sparidae)* are well represented in India, but only those of the genus *Chrysophrys* appear suitable for pond-culture. The different species run generally from a foot to 18 inches in length. Shoals of their young are frequently met with in backwaters at the beginning of the south-west monsoon and they have the same habit of working up estuaries against the current as is characteristic of European species. They make excellent eating and might prove useful fish for pond-rearing.

The KODUVA (*Lates calcarifer*) is a large fish highly valued, and well known to Europeans in Calcutta under the names of *begti* and Cock-up. It is one of largest of Eastern sea-perches and is almost the only species which frequents backwaters and tidal rivers, so agreeing in habit with its European relative the bass (*L. lupus*). In Pulicat Lake it abounds, particularly in the inner or northern section, where the fishermen of adjoining hamlets co-operate periodically in extensive driving operations using cotton rope nets of great strength and large mesh, the fish often ranging between 2½ to 3 feet, the maximum recorded being 5 feet with a weight of 200 lb. The air-bladders (sounds) of these fish are valuable for isinglass manufacture, so this fish well deserves attention for fish-cultural purposes. Its voracity may prove an objection, unless some cheap source of suitable artificial food can be provided. Otherwise it should thrive well in captivity.

The so-called "whiting" of Madras, SILLAGO SIHAMA the *karangan* of the Tamils, is yet another excellent food-fish, particularly well adapted to pond-culture. This and

a second species, *S. panijus*, readily adapt themselves to brackish water; they are fond of ascending tidal rivers and of living in backwaters. They are compact little fish seldom reaching a foot in length but esteemed amongst the most wholesome of the fish brought into Madras market. Special attention should be given to these fish in any cultural experiments that may be attempted in backwater ponds.

SMELTS.—As food for carnivorous fishes such as eels and polynemids, smelts will occupy an almost indispensable position in the economy of Indian fish-farms. They belong to the genus *Atherina* of which several species are found in abundance in Indian waters. Like their congeners in Europe, they affect backwaters and estuaries in shoals of immense numbers during the fry stage, which occurs during the cold season. Thus on Christmas day 1908, the Ennore backwater was literally alive with the fry of *Atherina forskali* ranging in size from $\frac{5}{8}$ to 1 inch in length. Children were catching them in large quantities by the simple expedient of sieving water through their cloths. A push-net used in the shallows at this season would supply ponds of polynemids with enough food to last them for months.

FLATFISH.—Certain of the Indian species of flatfishes are capable of thriving in brackish water, notably several of the tongue soles, *Cynoglossus* spp. and the plaice-like *Pseudorhombus arsius*. These are prime table fish, and as soon as a preliminary investigation shall have made us acquainted with their breeding habits and the nature of their habitual food, we shall be in a position to rear them in quantities to adult size. Immature individuals are caught at times in immense numbers in many of the West Coast backwaters, and these catches should prove invaluable to enable ponds to be stocked with fish which have already emerged successfully from the myriad dangers that beset them as fry.

CATFISHES, especially of the genera *Arius* and *Macrones*, would live and thrive well in mud-bottomed ponds, but their market value is so trivial that it would not pay to rear them in confinement, indeed vigilance will have to be exercised to ensure their exclusion.

The list above given by no means exhausts the number of species which appear capable of living and

thriving in confined areas liable to become more or less brackish during the rains. These other species are however of minor importance, either in little esteem for the table or too small to be useful except as food for bamin, eels or begti.

The number of really useful species which are available, namely, bamin or kala, mullet, kodava, sea-bream, *Sillago* (Madras whiting), smelts, plaice, soles and eels, include all that are considered of importance either in the Arcachon fish-ponds or in Comacchio lagoon, and there is reason to believe that the bamin and the kodava, both of greater value from the Indian standpoint than either mullet or eels, will prove susceptible of propagation and rearing in enclosed areas. Neither of these species is available in Europe, so marine pisciculture in India has the initial advantage over Europe of having both better quality and a greater number of suitable fishes wherewith to experiment. The rate of growth in India is probably much more rapid, but upon this no data are at present available.

The Waters available and suitable for Marine Fish Culture in Madras; their Characters and Extent.

The places susceptible of conversion into fish farms fall under three heads, namely :—

(*a*) Backwaters and estuarine creeks.
(*b*) Salt pan channels.
(*c*) Estuarine or deltaic marshes.

(*a*) The first category includes all the large areas of landlocked tidal water wherein fish rearing can be carried on. I say advisedly rearing and not culture, for in the case of ponds having an area of more than a few acres, a modification of the natural culture as practised at Arcachon and Comacchio must necessarily be the system pursued in contradistinction to that intensive or artificial culture whereby fish are reared from artificially impregnated ova and fed partly upon artificial food, a system applicable only to ponds of comparatively small area. Both the east and west coasts of the Madras Presidency abound in backwaters, many of them veritable inland seas. On the East Coast, Pulicat lake is the largest of these tidal lakes, having a waterspread of 178 square

miles in the rainy season. Covelong and Dugarazapattanam are two others of large size well designed by nature for conversion in part into fish farms that might easily surpass Comacchio, were capital and organisation available. The backwaters on the West Coast are even more extensive than these two latter; they are richly supplied with branches and side-creeks which swarm with myriads of fry at the commencement of the rains and which require little else than bunding off from the main channel to convert them into natural fish-ponds of any required area.

The side creeks, of all manner of size and aspect, given off in great numbers by all the great rivers in the neighbourhood of their embouchures are equally suitable for natural fish culture on a large scale wherever they can be cut off securely by bunds from overflow by flood water. In the deltas of many of the great rivers on the East Coast there are often to be seen long stretches of quiet water representing channels forsaken by the river for some new outlet; these old channels are often ideal situations for fish rearing as they are well within tidal range and would also afford frequent opportunity for freshening with sweet water when this became desirable.

The presidency is particularly favourably situated for the inception of large schemes for the natural cultivation of sea fish on the Venetian system. So many places are so perfectly adapted for it, that it is difficult to point to one as being notably superior; all circumstances considered I am inclined to think that whereas Dugarazapattanam backwater may be equalled, it cannot readily be excelled as the site of a lagoon fish farm. The area available is ample in acreage, the depth is of the requisite shallowness, a sufficiency of fresh water is available during the rains to reduce salinity and induce a strong run of fry whereof multitudes belonging to suitable species swarm in from the sea on the annual opening of the bar; finally, prescriptive fishing rights are non-existent in the backwater, the fishing population being most meagre, their operations virtually limited to the open sea. In such circumstances the initiation of a fish-farming industry at this centre would come as a boon to a population living under conditions

of marked poverty—the prosperity of coastal villages in this district having suffered considerable diminution through the competition of the East Coast railway with the coasting trade and with the Buckingham Canal, formerly the highway of traffic up and down the coast.

(*b*) *Salt-pan channels.*

One of the most promising openings for sea-fish culture, properly so-called, appears to lie in the utilisation of the salt water feeder channels at certain of the many Government salt factories dotted along the East Coast. The channels in question usually connect by means of well-built sluices with neighbouring tidal creeks; their function is to convey sea water to all sections of the salt pans within each factory. Very commonly the channel makes the circuit of the pans which it feeds by the intermediary of smaller channels at a higher level; this main channel has the form and appearance of a moat surrounding the salt pans. On the outer margin through a great part of its length it is bounded by a substantial embankment rising usually to 2 feet or more above the highest flood level of the adjoining creek and considerably more than this height above high water of spring tides. The principal channel is maintained several feet in depth, nominally 6 feet, I understand. Somewhere in its course the channel usually widens into a pond-like expansion of varying depth or there may be several of these.

From the channel and its branch ponds water is raised by various kinds of lifts into the high level gutters. It is used solely as a canal to furnish the supplies of salt water required for the manufacture of brine; provided this function be maintained it does not matter to the salt lessees what secondary use be made of the channel. Fish-culture in the main waterway of many factories can undoubtedly be carried on without detriment to the manufacture of salt; it may, where considered necessary, be restricted to particular sections, permeable barriers being placed where needful to prevent fish entering the sections where water is being taken out for brine making. What the salt makers want is an ample supply of clean saline water; in fish-culture the same need prevails, hence it follows that being

equally necessary for both industries, there could arise no disagreement, while in the event of fish-culture being carried on concurrently with salt making, the work of the fish-tenders being directed to the maintenance of the water and the channel in a clean and wholesome condition, the water supply for the pans would, if anything, be benefited. It is a matter of common knowledge that the presence of fish in a pond has a direct influence for good, the water undergoing distinct purification through the removal of matter that would otherwise putrify and tend to contaminate it.

However no decision need be come to on this question for some time and by then we shall be in possession of concrete data, for there exist some salt factories where the feeder channel although present, is in disuse, water for the pans being obtained in pits by percolation. Here then are no possible difficulties in the way of instituting a working experiment and if that should prove successful and it be found, as I am sure it will, that such operations in no way interfere with the regular routine of the factory and actually have a beneficial effect through rendering the water supply cleaner and more wholesome, then the Madras Government may utilize the channels of many of its salt factories for a remunerative secondary industry at almost no extra cost, seeing that nearly all the machinery for such work is already in existence in the shape of sluices, channels, and protective embankments.

(*c*) *Estuarine and deltaic marshes.*

On both coasts there are hundreds of square miles of low-lying ground bordering the lower reaches of our rivers which are overflowed whenever the adjoining stream comes down in flood or when high spring tides invade the estuary. It has been from land of this nature that salt pans have been formed and in the same way it would be a matter of little difficulty to make fish ponds of whatever area might be required.

Even as it is the marshy land adjoining many streams on the Malabar coast is the scene of a crude and undeveloped attempt at fish rearing, an attempt containing the germ of true fish-farming. The land in question is very low and is cultivated in plots at the time of the rains by

the soil in places being heaped up in raised beds, small plots rising from the excavated or lower level. With the advent of the wet season the latter areas become flooded and paddy is sown upon the raised plots which rise like islands above the surface of the flood. Concurrently a low bund is raised to enclose the general area dealt with in order to retain a supply of water as the rivers soon fall too low to maintain a proper inundation of the paddy planted plots. In the shallow stretches of water thus retained by bunding, fish fry which came up the river during the height of the flood are imprisoned in countless myriads. After the paddy is harvested, the water is still kept bunded to retain the little fish, which are collected and sold as soon as the water begins to dry up. Such or similar lands require but a limited expenditure to convert them into excellent fish farms for the intensive culture of mullet, bamin, and eels if properly selected within easy reach of a tidal supply of salt water.

The area of marshy estuarine land of this description is practically unlimited ; much of it is too saline for agricultural purposes and lies waste and unprofitable at the present time.

Procedure most likely to prove successful under Local Conditions in India.

As already mentioned two distinct systems of fish culture are indicated as applicable to Indian saline waters, (*a*) the natural, as practised at Arcachon and Comacchio and (*b*) the intensive which hitherto has never been carried out commercially except to a limited extent in Japan where it is confined to mullet and eels. Each system has its merits under definite conditions and each is susceptible of many modifications dependent upon the varying nature of local conditions at different parts of the coast, upon the species of fish to be reared, upon the acreage available, the financial resources disposable, and in less degree upon a number of other considerations peculiar to each location and its neighbourhood. Each culture pond and each natural fish farm must be designed independently with due regard to these various influencing conditions ; the environment of each establishment must receive full consideration.

Much of these necessary data is not yet available; observations are urgently needed upon the breeding habits and the nature of the food of the principal backwater and estuarine fishes and experiments in artificial impregnation and hatching are needed before marine fish-culture can be carried on commercially with fair assurance of eventual success.

Most useful information will become available if a well considered experiment in fish rearing be carried out by this department's officers in such a series of ponds as are available at trivial expense by the conversion of disused salt channels at several selected localities along the East Coast. Detailed proposals to this end will be prepared and presented separately. It is of interest to note that the Arcachon fish farms were begun in this very way—by conversion of salt-pan channels into ponds.

Comparison of local waters and conditions so far as are known, with those of Europe holds out definite promise of success if plans be well drawn up and the work judiciously managed. Several of the most important conditions in India are greatly more favourable than in Europe; we have more and better species of fish available from which to select the kinds which will repay culture most profitably and the rate of the growth is, we believe, much more rapid than in temperate latitudes * owing to the great abundance of food in inshore and estuarine waters and the absence of inclement winter conditions when growth suffers arrestment in Europe.

Natural fish farming, based upon the rearing of fish from fry hatched naturally in the sea involves so little expense that under these specially favourable conditions commercial success should be easy of attainment. Once the pond be made and the sluices fitted—and these exist already if we utilize salt-pan channels—almost the only expenses involved consist of the wages of a sluice man and a watchman. The fish under this system forage in the pond for the whole of their food and receive or require practically no attention save in regard to peri-

* The data obtained from our oyster-culture experiments at Ennore are most definite in regard to this shellfish; we have learned that eighteen months from spawning are sufficient to provide well-grown oysters fit for market, ranging in size between $3\frac{1}{2} \times 3$ inches and $4\frac{1}{8} \times 3\frac{1}{4}$ inches.

odical freshening of the water and the throwing into the pond of any live food caught in the sluice passage during this operation. The disadvantage of this system is that control over the species admitted and reared is far from complete. It is a matter of the greatest difficulty to keep different species separate—indeed under Arcachon and Comacchio methods all comers are welcome and all are herded together indiscriminately. As a consequence the hardy and voracious eel flourishes at the expense of the other fish, the mullet coming next. Now in India there is at present no demand for the eel. Except if prepared for export this fish would not pay to be grown; indeed unless the fishes more valued locally can be reared separately, the presence of large numbers of eels in culture ponds would prove detrimental and might easily prove fatal to the commercial success of the operations. Intensive culture of fishes which command a high price in local markets is more likely to pay better than natural culture provided such fish can be put upon the market in prime condition. If it be found possible to rear pomfret and polynemids in ponds without excessive trouble or expense, the esteem in which these fish are universally held will determine these species as the most profitable for intensive culture. Separate ponds would probably be required for these two fishes, mullet being added to the pomfret pond. But we must first find whether the last named fish is susceptible of culture in confined areas. In true intensive culture, arrangements would be necessary to supplement the natural food supply of the ponds by means of artificial food made from slaughter-house refuse, fish waste and fish meal obtained by grinding up excess catches of sardines and catfish which otherwise would be utilised for no other purpose except manure. To ascertain how far the comparatively low rates obtainable for fish in this country will permit of this phase of intensive culture is one of the primary tasks to be undertaken in any practical experiments in marine fish-farming.

TUTICORIN,

27*th November* 1910.

JAMES HORNELL.

FIG. 7.—FISH LABYRINTH, SERILLA FISHING STATION, COMACCHIO. VIEW FROM THE COVOLA LOOKING TOWARD APEX OF FIRST SET OF PALISADES.

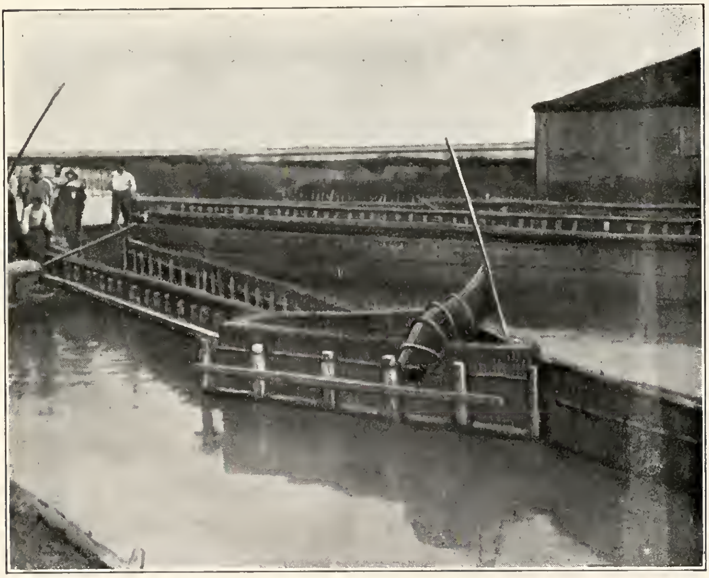

FIG. 8.—THE SAME LABYRINTH SHOWING A LATERAL OTELE WHEREIN THE EELS ARE FINALLY TRAPPED.

[*J. Hornell, Photo.*]

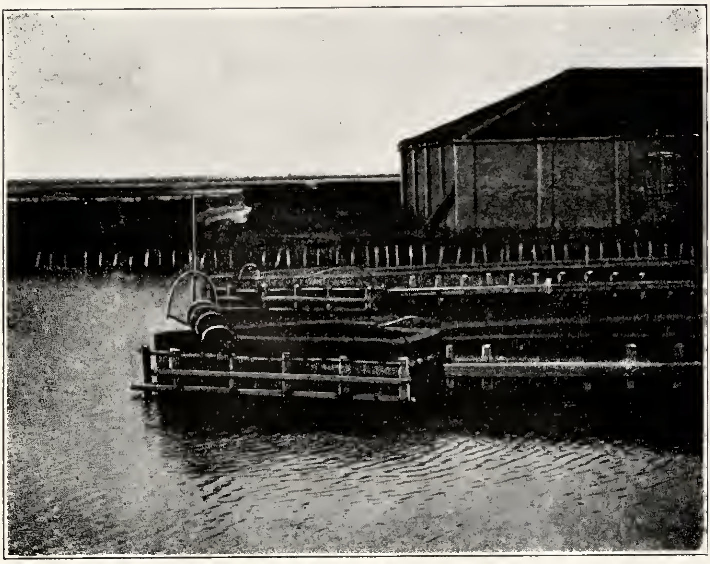

FIG. 9.—VIEW OF THE TERMINAL TRAPS (OTELI) OF TWO TWIN LABYRINTHS, SERILLA FISHING STATION, COMACCHIO.

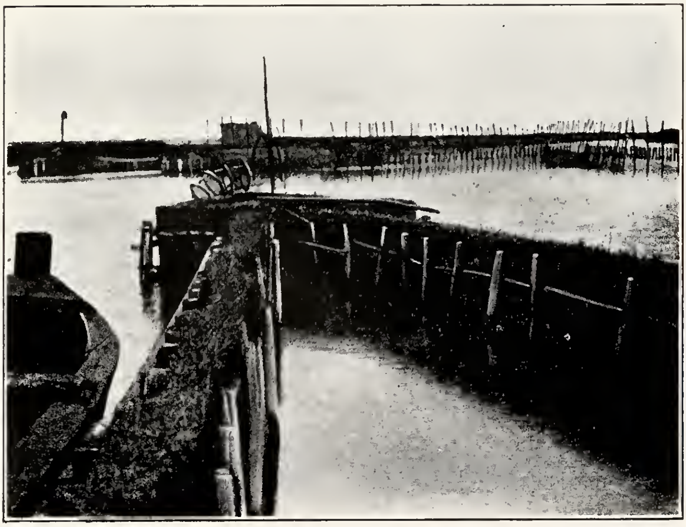

FIG. 10.—VIEW FROM WITHIN THE COGOLARA OF ONE OF THE SAME LABYRINTHS, LOOKING TOWARDS THE MOUTH OF THE TERMINAL OTELE.

[*J. Hornell, Photo.*]

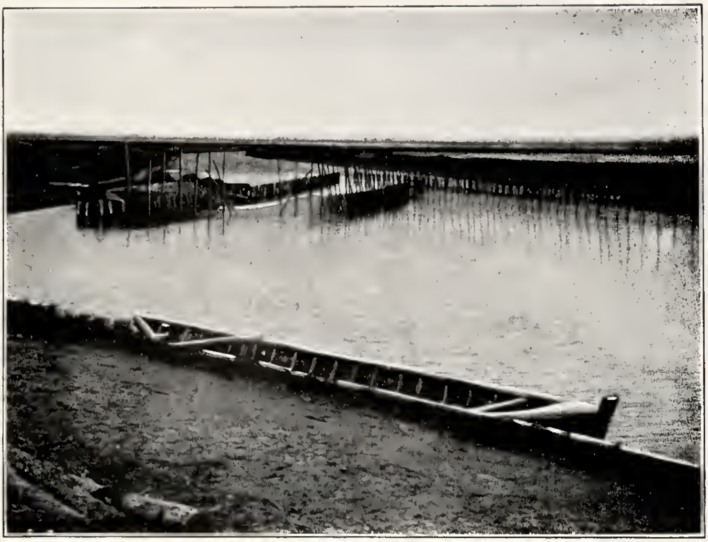

FIG. 11.—VIEW FROM SERILLA FISHING STATION TOWARDS ITS SEA-CANAL (CANAL UNGOLA).

FIG. 12.—A LOCK ON A SERVICE-PASSAGE LEADING FROM A SEA-CANAL INTO VALLE CONA, COMACCHIO.

[*J. Hornell, Photo.*]